USAAMRDL-TR-77-13

CRASHWORTHY TROOP SEAT TESTING PROGRAM

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Fort Eustis, Va. 23604

APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

This report was prepared by the Boeing Vertol Company, a division of the Boeing Company, under the terms of Contract DAAJ02-74-C-0036. The objective of this effort was to demonstrate the validity and practicality of a proposed draft military specification for helicopter troop/passenger seats. This was achieved by the design, fabrication, component testing, static testing, and dynamic testing of lightweight forward- and aft-facing troop seats. The proposed draft military specification contained in this report has yet to be coordinated, finalized, and published. Once published and implemented, however, the crashworthy troop/passenger seat military specification will ensure that the passengers of future Army troop transport helicopters will be afforded a higher probability of survival during a crash impact.

This report has been reviewed by this Laboratory and is considered to be technically sound. The technical manager for this program was Mr. Geroge T. Singley, III, Structures Technical Area, Technology Applications Division.

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Crashworthy troop seat designs developed under a previous contract were reviewed and design refinements were made. Component testing was planned and tests were performed. Malfunctioning components were redesigned and were retested satisfactorily. A new tubular-strut energy attenuator was developed to replace the rolling helical-wire energy attenuator which did not function properly.

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20. ABSTRACT (continued).

Crashworthy troop seats fabricated under a previous contract were modified, with new components developed during component testing. Additional seats were fabricated for static testing in various crash impact attitudes. A total of six static tests, including two retests required as a result of minor failures, were performed by Dynamic Science as a subcontractor. Analysis of the test results showed that the forward- and aft-facing seat configurations were highly successful in meeting the test objectives in all attitudes, with the exception of the lateral loading. A failure occurred at a lateral loading value which was just under the test load objective. Minor modifications would permit meeting the test objective.

Eleven dynamic tests were performed by FAA-Civil Aeromedical Institute in three series of tests. Seat improvements were made between test series, with the result that the final tests were successfully performed. Modifications to the test criteria were incorporated in the proposed Military Specification, Seat, Helicopter, Troop.

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Appreciation is extended to Stan Desjardins and Alan Lane of Dynamic Science Inc., Phoenix, Arizona, who performed the static testing, and to Ed Trout and Dick Chandler, for their support during the dynamic testing at the FAA-Civil Aeromedical Institute, Oklahoma City, Oklahoma.

INTRODUCTION

BACKGROUND

The poor crash impact performance of helicopter troop seats designed to current military specifications was revealed by the U.S. Army in the early 1960's through accident investigations, full-scale crash tests, and critical review of the applicable specifications. It was discovered that numerous troop seat occupants were being injured during moderate impacts because of inadequate upper torso restraint, and inadequate seat strength. The ultimate load requirement amounted to approximately 8G vertically on the seat pan, 3G on the back and 1G side loading. There were no significant means of vertical crash-force attenuation, and testing criteria and methods were inadequate. Crashworthiness design criteria for improved troop seat design were developed and published in TCREC Technical Report 62-79 (Reference 1). Several experimental troop seat concepts designed in accordance with these criteria were subsequently developed and tested as described in TRECOM Technical Reports 63-62 (Reference 2) and 65-6 (Reference 3). These efforts (1) demonstrated that the TCREC TR 62-79 crashworthiness design criteria are technically attainable, and (2) led to the inclusion of these criteria in USAAVLABS TR 67-22 (Reference 4), "Crash Survival Design Guide".

Development of crashworthy troop seats has continued at a slow pace because of the formidable list of requirements which the seats must meet. Some of those requirements are as follows:

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[1] Turnbow, J.W., et al., CRASH INJURY EVALUATION, Aviation Crash Injury Research, Phoenix, Arizona; TCREC Technical Report 62-79, U.S. Army Transportation Research Command, Fort Eustis, Virginia, November 1962.

[2] Turnbow, J.W., et al., CRASH INJURY EVALUATION, DYNAMIC TEST OF AN EXPERIMENTAL TROOP SEAT INSTALLATION IN AN H-21 HELICOPTER, Aviation Safety Engineering and Research, Phoenix, Arizona; TRECOM Technical Report 63-62, U.S. Army Transportation Research Command, Fort Eustis, Virginia, November 1963.

[3] Weinberg, L.W.T., CRASHWORTHINESS EVALUATION OF AN ENERGY-ABSORPTION EXPERIMENTAL TROOP SEAT CONCEPT, Aviation Safety Engineering and Research, Phoenix, Arizona; USATRECOM Technical Report 65-6, U.S. Army Transportation Research Command, Fort Eustis, Virginia, February 1965, AD 614582.

[4] Turnbow, J.W., et al., CRASH SURVIVAL DESIGN GUIDE, Aviation Safety Engineering and Research, Phoenix, Arizona; USAAVLABS Technical Report 67-22, U.S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, December 1967, AD 656621.

Low cost and weight, high strength, stowability in a small space, rapid removal and folding, adjustability for troops with and without field equipment, adequate support for shoulder restraint, operational simplicity for troops unfamiliar with restraint devices, clear seat area for rapid ingress and egress, stabilized stroking under all impact attitudes, energy-attenuating devices which are reliable, repeatable, and not affected by environmental conditions, and are adaptable to the wide range of troop and equipment weights.

A crashworthy troop seat was selected from a number of proposed concepts and was developed to meet the above requirements. This development and operational suitability evaluation is discussed in USAAMRDL-TR-74-93 (Reference 5)[5]. Structural strength and crash impact energy attenuation features remained to be evaluated and are the subject of this report.

PROGRAM OBJECTIVES

The crashworthy troop seat testing program principal objectives were as follows:

- Determine satisfactory functioning and strength of critical components such as energy-attenuating devices.
- Determine seat system stability and strength during crash impact loading and stroking.
- Determine seat's capability of attenuating crash impact on occupant.
- Substantiate or revise a proposed Seat, Helicopter, Troop Military Specification based on test data.

SCOPE

The crashworthy troop seat testing program was divided into the following tasks:

Task I - System analysis and component testing

Task II - Static testing and analysis

Task III - Dynamic testing and analysis

[5] Reilly, M.J., CRASHWORTHY TROOP SEAT INVESTIGATION, Boeing Vertol Company, Philadelphia, Pennsylvania; USAAMRDL Technical Report 74-93, Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, December 1974, AD A007090.

CRASHWORTHY TROOP SEAT TESTING - TASK I

TASK I - REQUIREMENTS

The required Task I effort was as follows:

1. Review troop seat designs performed under Contract DAAJ02-72-C-0077 (Reference 5) and identify components requiring design refinements.
2. Survey restraint systems (using commercially available components).
3. Prepare test plan for component tests.
4. Test components.
5. Finalize detail design to comply with test results.
6. Analytically verify design to assure that it complies with environmental, strength, crash-force attenuation, and other performance requirements of the draft Military Specification, Seat, Helicopter, Troop.
7. Establish test plan for static tests.

Each of these areas is discussed in the above order.

REVIEW AND IDENTIFICATION OF REFINEMENTS

Drawings and analysis of the crashworthy forward-facing troop seat developed under USAAMRDL Contract DAAJ02-72-C-0007 were reviewed to determine the adequacy of the troop seat for static and dynamic testing. Detailed stress analysis had been conducted on the principal seat structure and the seat was built in accordance with this analysis (Figure 1). Therefore, the seat was assumed to be capable of withstanding the tests. A preliminary analysis had been performed on the small components, such as toggle latches and floor quick-disconnects. A detailed analysis was not performed as it would have been complex, and individual tests of the components were determined to be the least expensive approach. The restraint system was adequate for the mock-up demonstrations (Figure 1) but did not meet the static and dynamic test requirements. Therefore, design of a new restraint system of adequate strength was necessary, using available components.

The headrests on the troop seats used for mock-up demonstration were of thin plywood and had to be replaced for the rearward dynamic loading condition. The foam pads used were soft and required replacement with an energy absorbing material.

Figure 1. Aircraft installation of troop seat mock-up.

The mock-up seat drawings showed only a forward-facing configuration. Modifications to the drawings were necessary to add details for an aft-facing seat configuration. Forward-facing seats can be converted to aft-facing seats by adding a bracket on the seat pan rear tube and by connecting the diagonal strut at the back of the seat instead of the front. Floor quick-disconnects used at the back of seats are also required at the front of aft-facing seats to permit the diagonal strut to be connected to the floor. Front diagonal cables require connection to the attenuator strut quick-disconnecting rather than to the individual disconnects used on forward-facing seats.

RESTRAINT SYSTEM

A survey was made of available off-the-shelf restraint system components and materials which would meet the strength and elongation requirements of the draft Military Specification, Seat, Helicopter, Troop. The buckle is the principal component of the system. A buckle with a minimum of four connecting points is required. Two attachments are for the two lapbelt ends and the other two are for the double shoulder straps. Design load requirements on the buckle are 4000 lb of tension on the lapbelt connections and simultaneous loading of 4000 lb on each of the shoulder strap connections. The only available buckle purporting to meet these requirements was a slide release buckle.

An available polyester webbing that meets the lapbelt and shoulder harness requirement of 5 percent maximum elongation at 4000-lb design load tensile strength was found. The webbing was 2 in. wide, 0.065 in. thick, had a 9024-lb minimum breaking strength, and was developed for the auto industry. Commercially available shoulder harness reels at 2000-lb design load were found which adequately met the dynamic test loads.

TEST PLAN - COMPONENT TEST

A test plan for static-testing components of the troop seat was prepared and is attached as Appendix A. The plan discusses testing of 11 components separately or in combination with other components. The following components are included in the test:

1. Seat-tensioning turnbuckle
2. Seat-tensioning toggle latch
3. Vertical energy attentuator (wire-bending)
4. Front diagonal energy-attenuating cable

5. Front quick-disconnect (floor attachment)

6. Front floor quick-disconnect stud

7. Diagonal stabilizing strut energy attentuator

8. Back quick-disconnect (floor attachment)

9. Back floor quick-disconnect stud

10. Vertical hold-down energy-attenuating cable

11. U-bracket and back quick-disconnect (floor attachment)

COMPONENT TESTING

Testing was performed in accordance with the procedure described in the test plan (Appendix A). As a result of problems encountered, some retests were necessary. The tests performed were as follows:

Test 1

A combination of components was used in Test 1. These components consisted of a seat-tensioning turnbuckle, a seat-tensioning toggle latch, and a vertical energy attenuator. Adapters were made for installing the assembly in the Instron tensile test machine (Figure 2). A tension load was applied to the specimen in stepped increments and inspections for deformation were made. The test was stopped when deformation of the toggle latch occurred (Figure 3). A maximum load of 1300 lb was recorded. There was no stroking of the wire-bending attenuator. The design stroking load is 1020 lb.

A second run was made, testing only the wire-bending attenuator. The peak starting load was recorded as 1555 lb, with a running load of 1400 lb (Figure 4). It was evident that the wire size was too large, so a new wire was fabricated using 0.100-in. diameter wire.

A third run was made using only the wire-bending attenuator. The design stroking load of 1020 lb was almost exactly achieved, varying plus and minus 10 lb from a 1030-lb mean (Figure 4).

The fourth run was made using the 0.100-in. diameter wire-bending attenuator in an assembly with the turnbuckle and modified toggle latch. The stroking force varied only slightly from the 1020-lb design load line, with fluctuations of plus and minus 5 lb. No deformation of the toggle latch occurred (Figure 4).

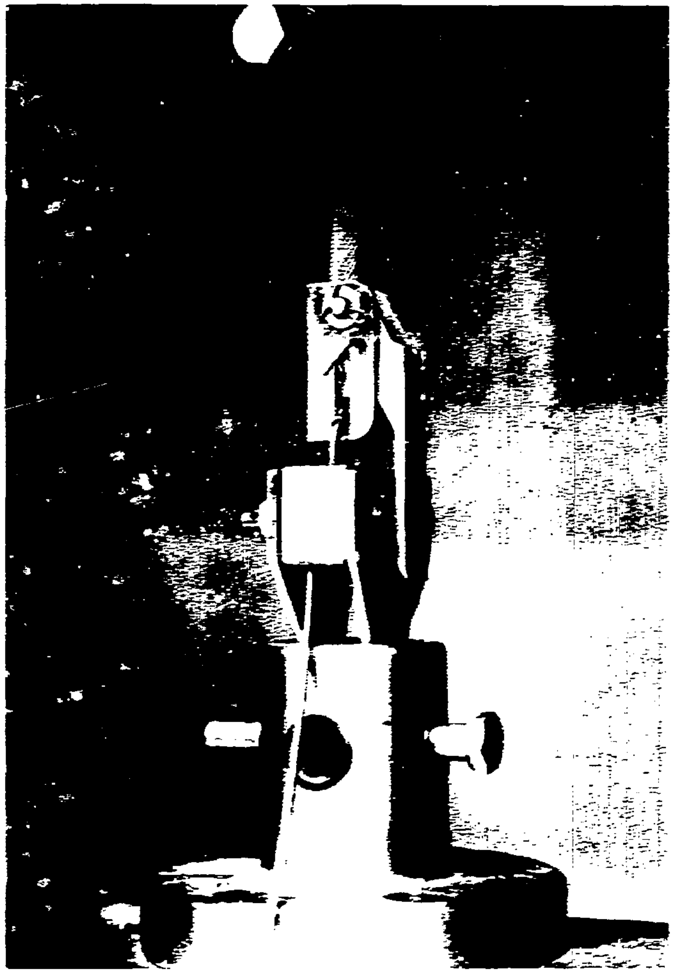

Figure 2. Vertical attenuator assembly (pre-test).

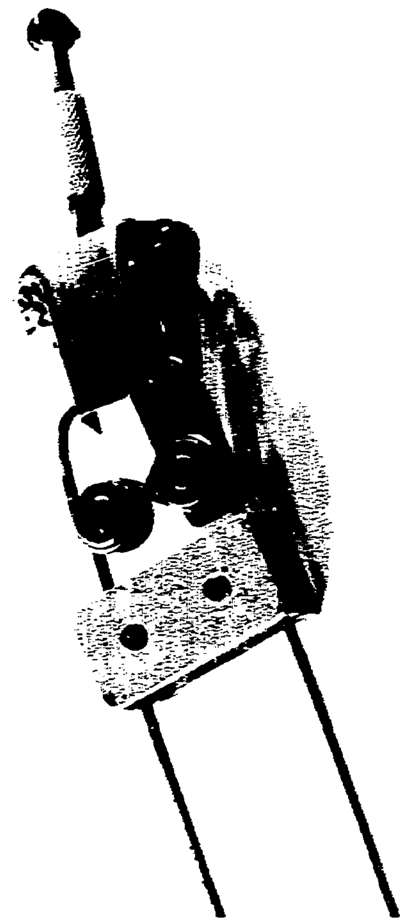

Figure 3. Vertical attenuator assembly (post-test).

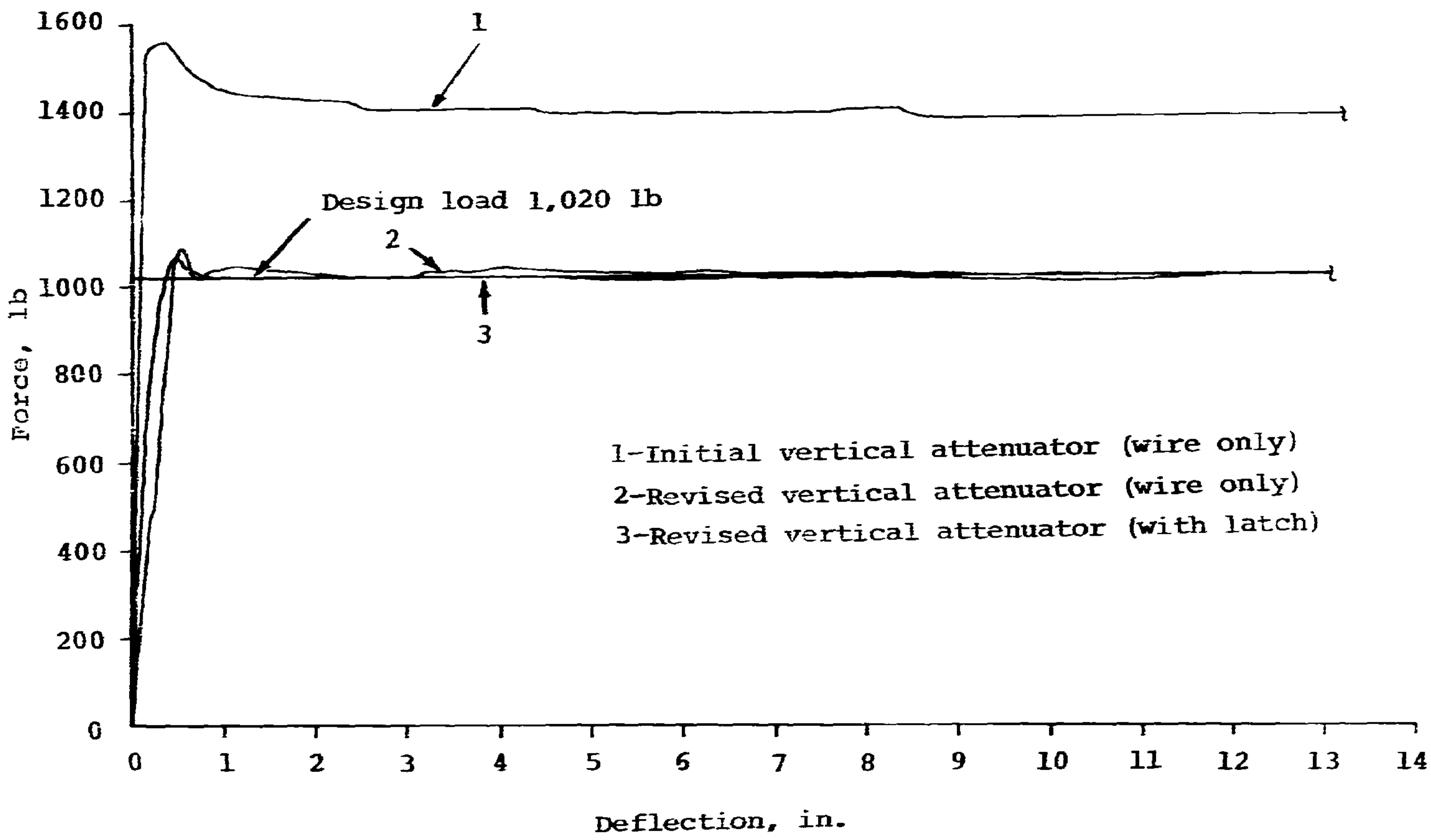

Figure 4. Vertical attenuator force deflection.

Test 2

Components included in Test 2 were the front diagonal energy-attenuating cable, floor quick-disconnect fitting, and floor quick-disconnect stud. The test specimen was installed in the Instron tensile test machine, using adapters to orient the end fittings as installed on the seat (Figure 5). The assembly was pulled at a rate of 10 in. per minute with stops made at intervals to inspect for deformations. A curvilinear force deflection curve characteristic of tensile yielding materials, was produced with an average force level approximately on the design force level of 1650 lb (Figure 6). The cable broke at 2000 lb after stroking 6 in. (Figure 7). This would permit an 8-in. lateral seat stroke, which is more than the lateral stroke needed. All of the remaining components in the assembly withstood the 2000-lb load without deformation.

Test 3

The telescoping-tube rolling helical-wire energy attenuator was tested in conjunction with the floor quick-disconnect fitting and the floor quick-disconnect stud. The attenuator was constructed using 6061 aluminum tubing and 2024 aluminum wire. The assembly was placed in the Instron tensile test machine (Figure 8). Adapters were used to hold the quick-disconnect fitting in the same orientation as used for the troop seat installation (Figure 9).

The design stroking load for the attenuator is 1360 lb. Tensile loading was applied to the attenuator in stepped increments until the load reached 1940 lb. At this load, the end fitting pulled out due to a weld failure (Figures 10 and 11). The attenuator stroked only 0.63 in.

A second attenuator unit was tested and required a 3500-lb force to cause 1 in. of stroke. After stroking 2 in., the force required to pull the attenuator dropped rapidly until it reached zero load at 9 in. of stroke (Figure 10). The wire was exposed in this test and showed signs of being fused together (Figure 12). Rolling of the helical wire element did not occur as intended.

The floor quick-disconnect fitting and floor stud withstood the 3500-lb load without deformation. This load is 250 percent of design load. A third attenuator unit was tested and it failed in the same manner as the first after reaching a load of 3250 lb. The unit had stroked 3 in. at the point of failure (Figure 10).

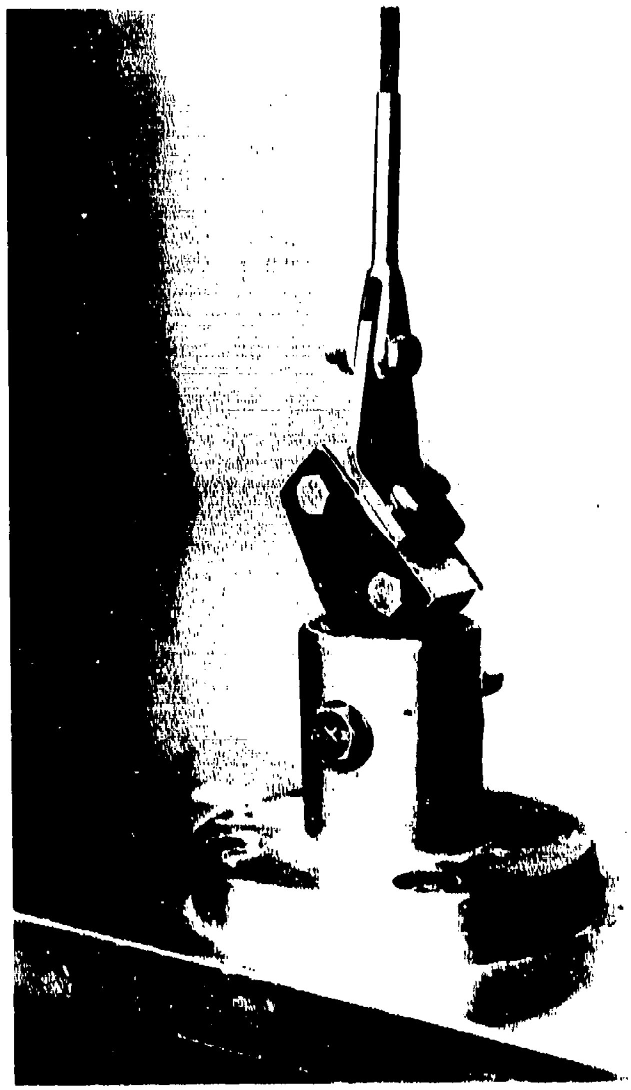

Figure 5. Floor quick-disconnect and diagonal cable (pre-test).

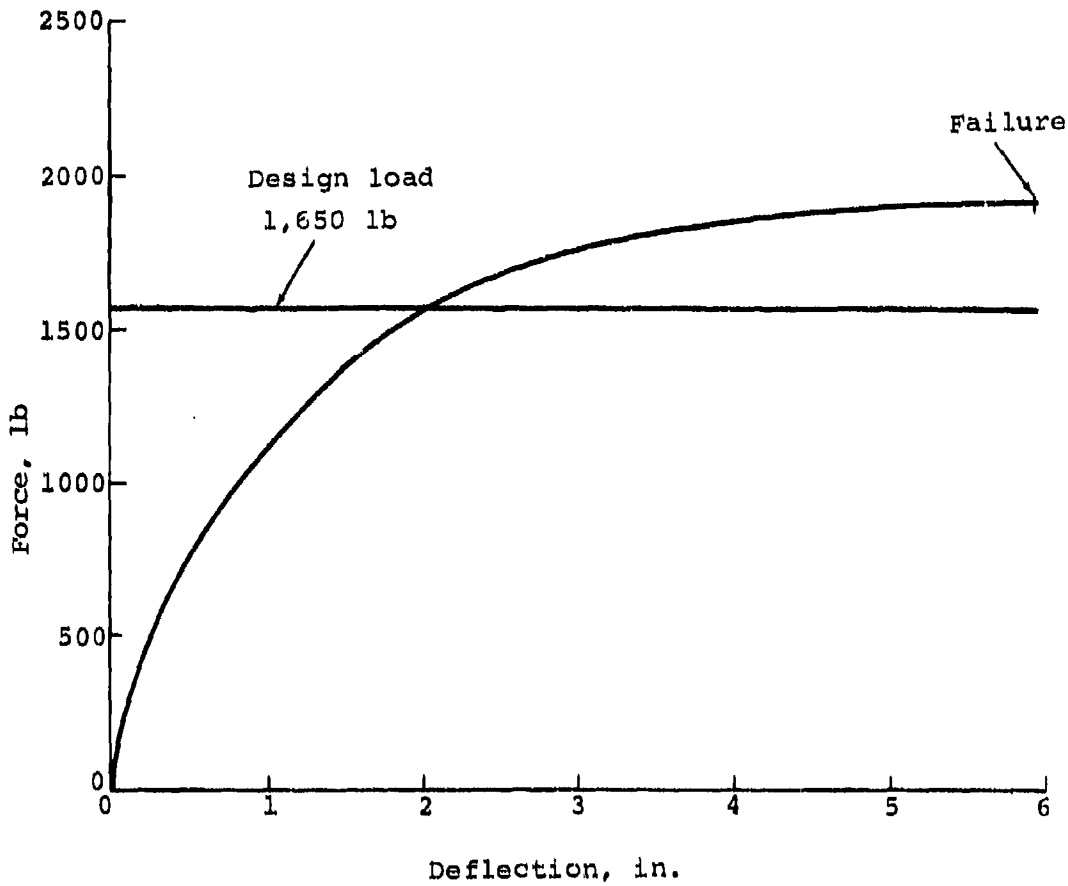

Figure 6. Diagonal cable energy attenuator force deflection.

Figure 7. Diagonal cable (post-test).

Figure 8. Instron tensile tester.

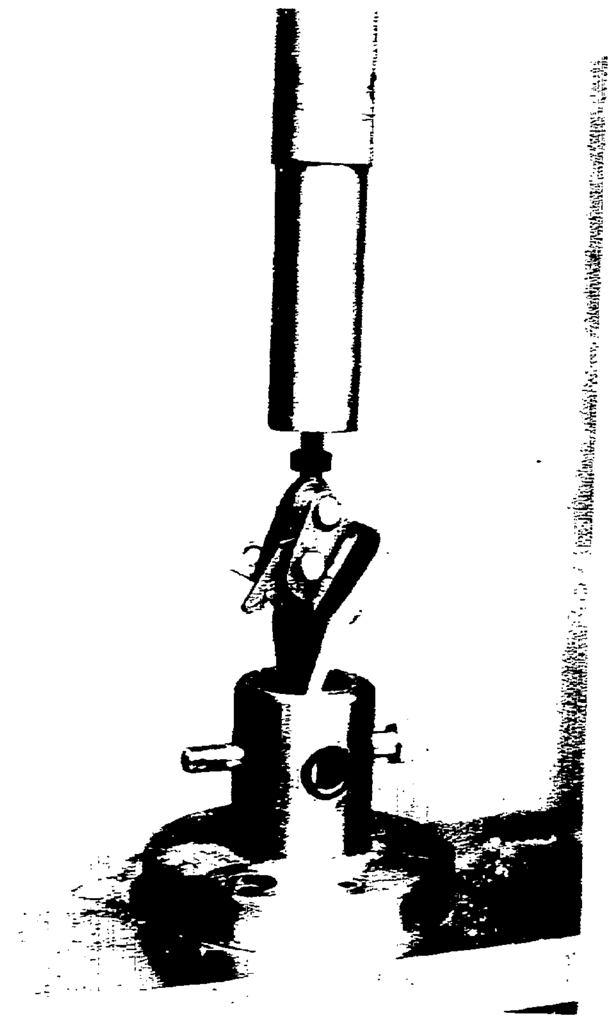

Figure 9. Quick-disconnect adapter.

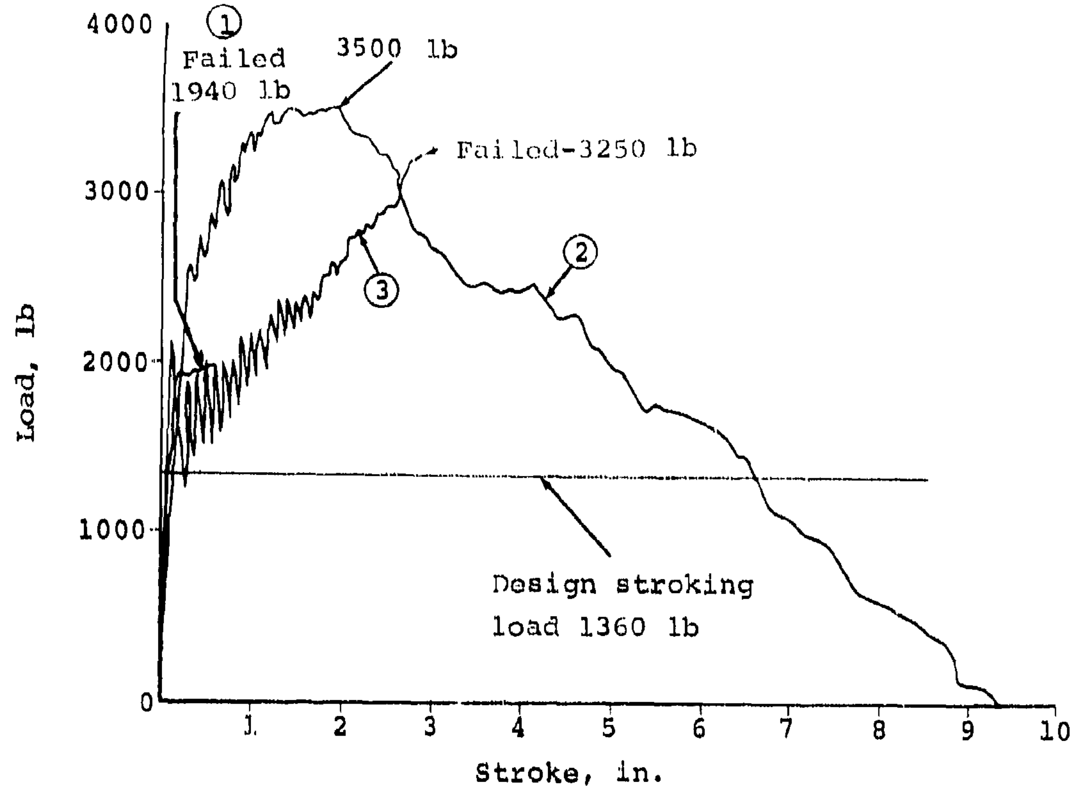

Figure 10. Aluminum-strut attenuator with aluminum helical wire.

Figure 11. Unit 1 (post-test).

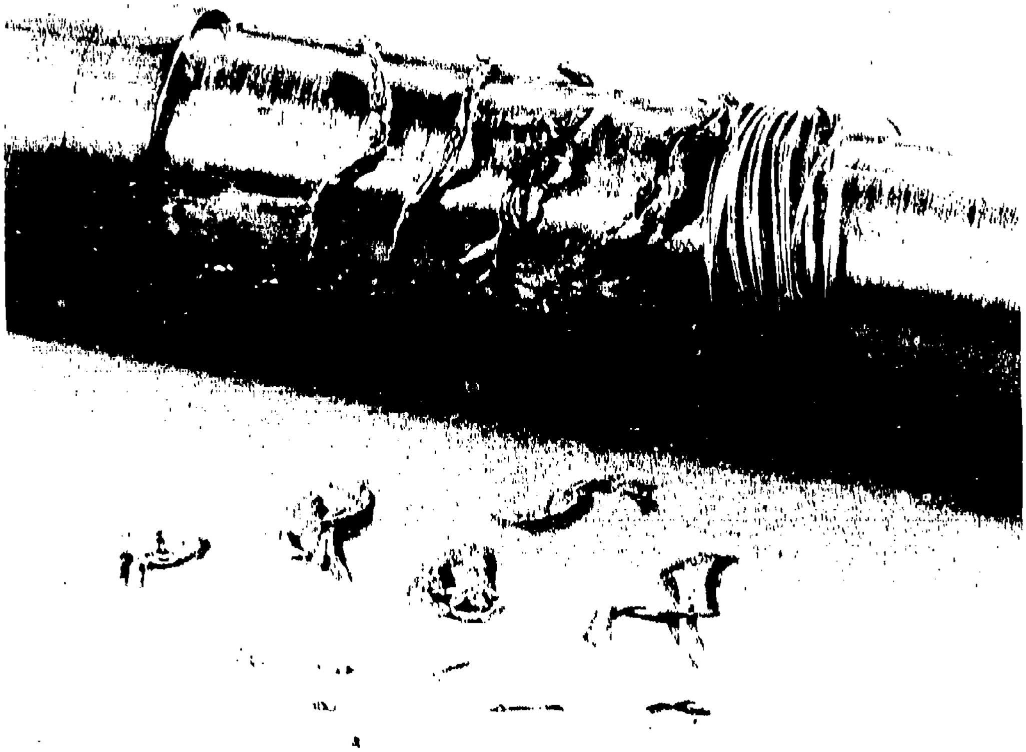

Figure 12. Unit 2 (post-test).

The units were returned to the vendor for redesign and 17 new units were returned. These new units were the same as the first, except that a stainless steel helical wire was used in place of the aluminum wire.

A test was conducted on a new unit and it failed to reach the design stroking load of 1360 lb. It peaked at 1090 lb and rapidly fell to 800 lb at 1-in. stroke, and to 450 lb at 7-in. stroke (Figure 13). Seven tests were conducted on the new units and a wide range of irregular patterns were produced, none reaching the design stroking load requirements (Figure 13).

Cause for the failure of the units to perform properly was investigated. It was observed that the surface of the outer tubes had ripples around their circumference and it was assumed that these were in the area of the helical wire. From this, it was concluded that the wire was causing the aluminum tube to cold-flow. Pressure between the wire and the inner and outer tubes was relieved by the cold flowing. The wire was captured in the grooves, and when load was applied to the units, the wire slid and did not roll as intended. Relief of pressure on the wire and the cold-flow grooves resulted in low resistance to loading and produced irregular load/deflection patterns.

A new attenuator was designed and fabricated and developmental tests were performed. This new configuration consists of a telescoping-tube strut with a wire-bending element inside the tube; details are discussed below.

The initial tensile test produced a flat force deflection curve, but the stroking load was 30 percent below the design load (Figure 14). Redesigns were made to the wire-bending element, to increase the bend angle of the wire. A second unit was tested in tension and the force deflection curve values were within design tolerances (Figure 14). Compression tests were conducted on the unit and the force level dropped approximately 20 percent. The unit was again recycled in a tension mode and the force level of the compression mode was maintained (Figure 14).

Testing of the first two units was accomplished without a wire terminal fitting at the end of the strut. The wire ends were clamped in the test machine for the tests. A method for terminating the wires had not been determined at the time of testing.

Individual tests were made of two terminal types. The first type attached the wires by swaging, and when tested, the wires pulled out at 50 percent of design load. The second type attached the wires by pinning; details are

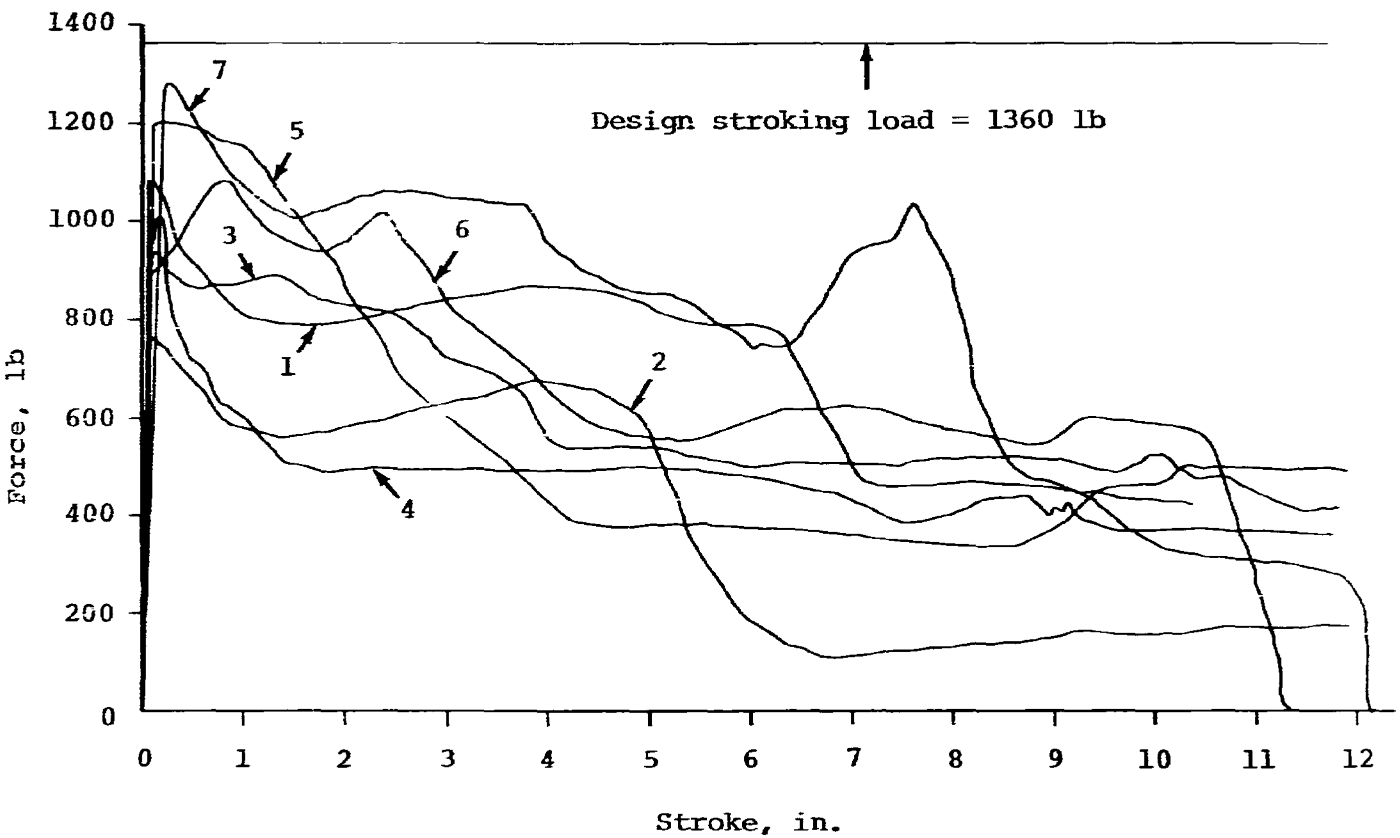

Figure 13. Aluminum-strut attenuator with stainless steel helical wire.

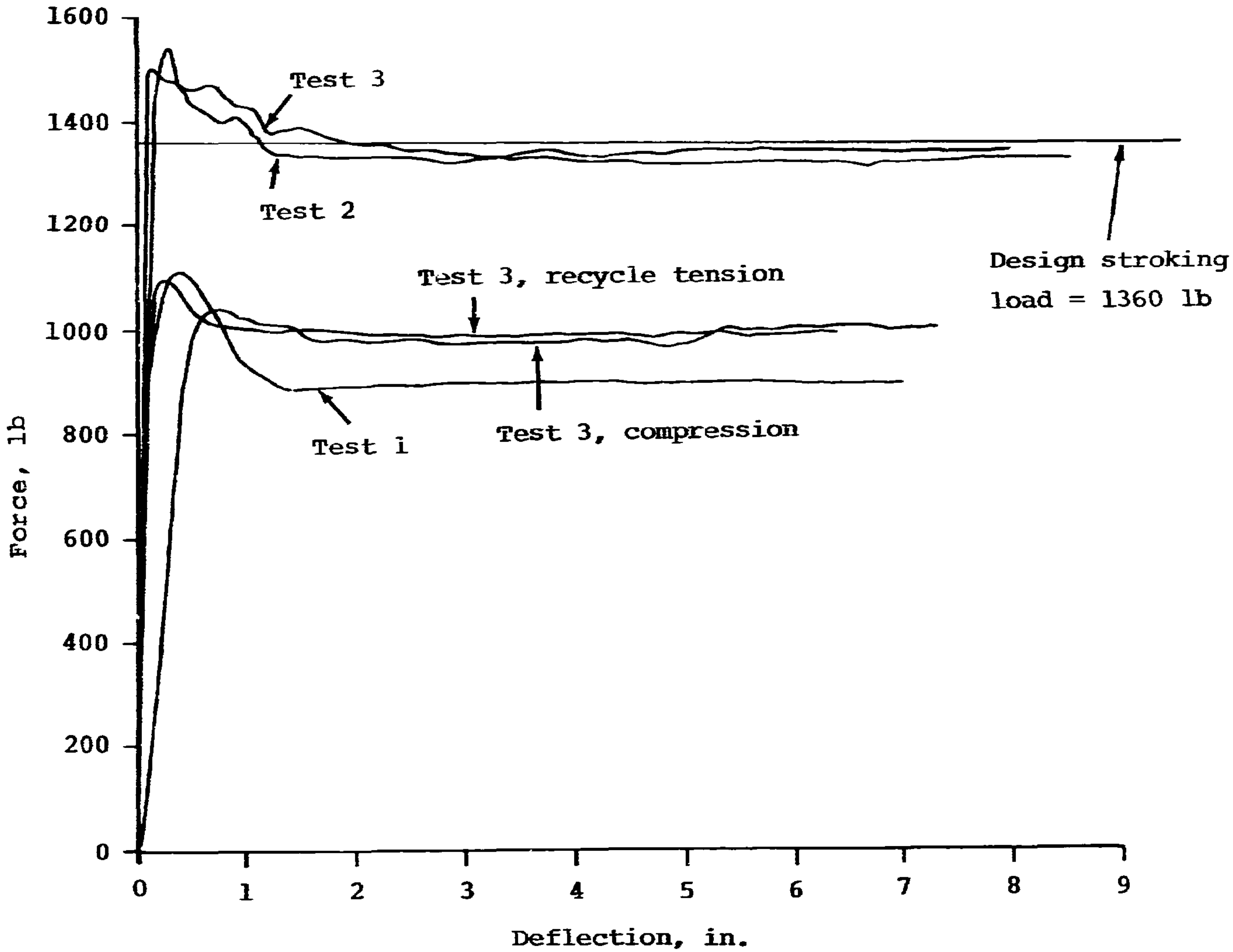

Figure 14. Tubular strut wire-bending attenuator force deflection.

described below. This unit was tested in destruction and satisfactorily reached 200 percent of design load (Figure 15).

A third energy-attenuator test specimen was fabricated, incorporating the pinned-type wire termination. Tests were performed on this unit and function and force/deflection results were satisfactory (Figure 14).

Test 4

The 1/8-in.-diameter vertical hold-down cable was tested in conjunction with the U-bracket, floor quick-disconnect fitting, and floor stud. The test specimen was installed in the Instron tensile test machine, using adapters to hold the end fittings in the same orientation as the fittings for the troop seat installation (Figure 16). The design load for the assembly is 1020 lb. The tensile load of the machine was increased until a load of 650 lb was reached. At this point, the cable pulled out of the swaged fitting. The test was repeated two more times and in each case, the cable pulled out at approximately the same load (Figure 17).

Methods of preventing the cable from pulling out were investigated and tests were made. The first method tried was to flare the end of the cable protruding through the fitting and to apply a lead/tin solder. The cable again pulled out at a slightly higher load. Silver solder was applied to the flared cable end and the assembly was tested. The cable did not pull out of the fitting while the design load of 1020 lb was applied. Loading was increased until the cable broke at a load of 1980 lb; the rated minimum breaking strength of the cable is 2000 lb. This is approximately 200 percent of design load. All of the remaining components in the assembly withstood the load without deformation. The method of swaging the end fitting to the cable was investigated and found to be faulty. Procedures were corrected and further tests proved the swaged configuration to be satisfactory.

DETAIL DESIGN FINALIZATION

Components determined by the test to need design modifications were as follows:

1. Vertical wire-bending energy attenuator
2. Toggle latch
3. Diagonal-strut energy attenuator
4. Vertical hold-down cable

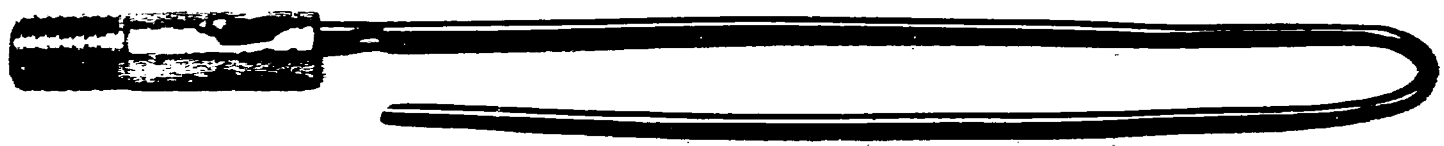

Figure 15. Notched wire and pin anchorage test specimen.

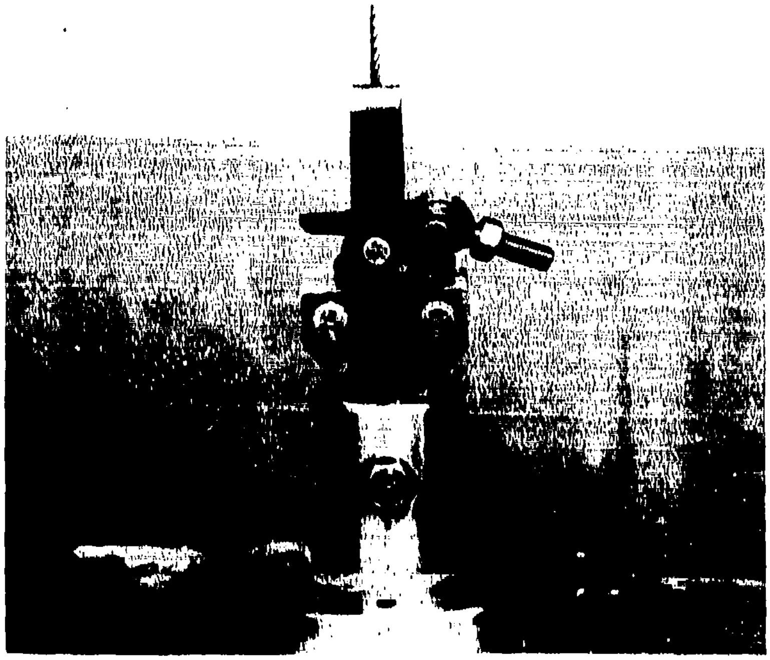

Figure 16. Quick-disconnect and hold-down cable.

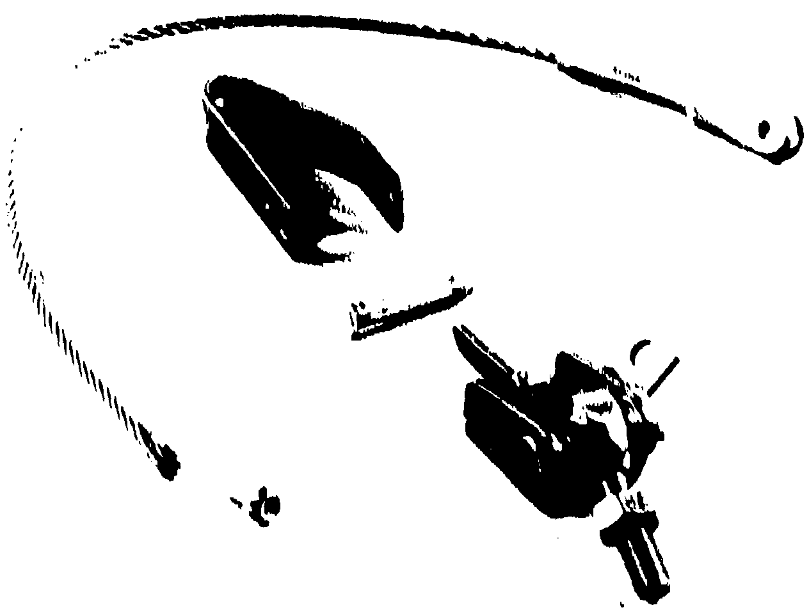

Figure 17. Failed hold-down cable.

VERTICAL WIRE-BENDING ENERGY ATTENUATOR

The stroking load for the initial wire-bending energy attenuator in the first test was found to be in excess of the desired value, causing deformation of the attachment components. To reduce the load, the wire size was reduced to 0.100 in. Improvements were made in the end of the wire by changing from an inverted U shape to an inverted V shape to improve attachment to the toggle latch. The initial configuration required threading through holes in the toggle latch. The revised configuration permits a simple pin attachment. The test of the revised unit proved to be satisfactory.

TOGGLE LATCH

Deformation of the toggle latch experienced during testing necessitated its being stiffened. The channel-shaped latch was reinforced by adding another channel section to form a box. The hinge ears on the original channel, which deformed in the test, were doubled in thickness by the added channel. Heat treatment of the 4130 steel used for the channels to 160KSI further improved the strength. Attachment of the wire-bending attenuator to the latch was improved by the new box configuration.

VERTICAL HOLD-DOWN CABLE

Attachment of the swaged fitting to the vertical hold-down cable failed to hold at the required load during testing. Silver-soldering the cable to the fitting proved to be satisfactory for meeting the load requirements but required special procedures during fabrication. High heat is needed to apply the silver solder to the cable, and heat anneals the cable, reducing its strength. Procedures for cooling the cable during soldering were required.

A decision was made that the best approach was to improve the swaging technique and to proof-test the cable assembly after swaging. Subsequent cable assemblies were fabricated using the improved swaging techniques, and proof tests to 1100 lb were made; this load is slightly greater than the design load.

DIAGONAL-STRUT ENERGY ATTENUATOR

The telescoping-tube energy attenuator using the rolling helical wire principal was found to be unsatisfactory during component testing. A substitute attenuator was developed which uses a wire-bending principle similar to that used in the vertical attenuator.

Wire-bending attenuators have been found by Boeing tests to be predictable, reliable, and free of environmental problems. The one disadvantage of the wire-bending attenuator is that it cannot take compression. The problem then was to develop an attenuator which will function in tension or compression while the wire-bending element operates in tension.

An attenuator was developed which uses telescoping aluminum tubes similar to the attenuator it replaced. A cap is placed on the inner end of the inner tube (Figure 18). Music wire of 0.100 in. diameter, in the shape of a hairpin is looped through the cap, and the two free ends are secured to a stud in the outer end of the inner tube. A trolley consisting of three rollers sandwiched between two plates bends the wire as it moves back and forth on the wire. The trolley is pinned to the outer tube and a slot is provided in the inner tube to allow the trolley to move relative to the inner tube (Figure 19).

Several methods of attaching the wire to the end stud were considered. The ends of the wire were roughened and then swaged in the fitting. Tests proved this method to be unsatisfactory. An Electroline wedge gripper was considered but was rejected due to size and weight. A third approach was to use the same study fitting used for swaging, but to pin the wires to the fitting. A hole was drilled between the two wire insert holes and the wires were notched. A pin was inserted in the hole to retain the wires (Figure 15). Tests to destruction were made and failure occurred at 200 percent of design load.

ANALYTICAL VERIFICATION OF DESIGN

The troop seat design was reviewed to determine its compliance with environmental requirements, maintainability, reliability, and other performance requirements of the draft Military Specification; Seat, Helicopter, Troop. (See Recommendations section of this report on p. 138)

Environmental Evaluation

An evaluation was made of the ability of the troop seat design to comply with the environmental requirements of the Military Specification; Seat, Helicopter, Troop, as detailed in the environmental test methods of MIL-STD-810. The following environmental factors were evaluated:

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[6]MIL-STD-810, Military Standards, Environmental Test Methods.

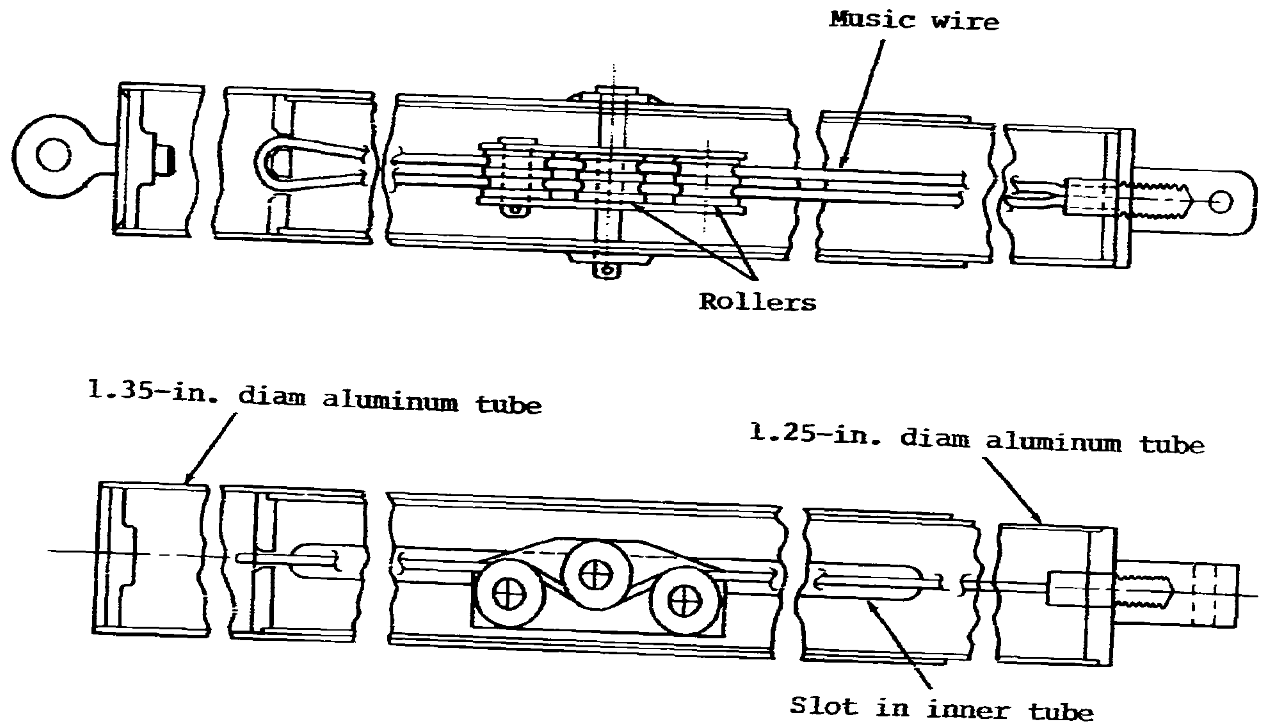

Figure 18. Wire-bending tension/compression energy attenuator.

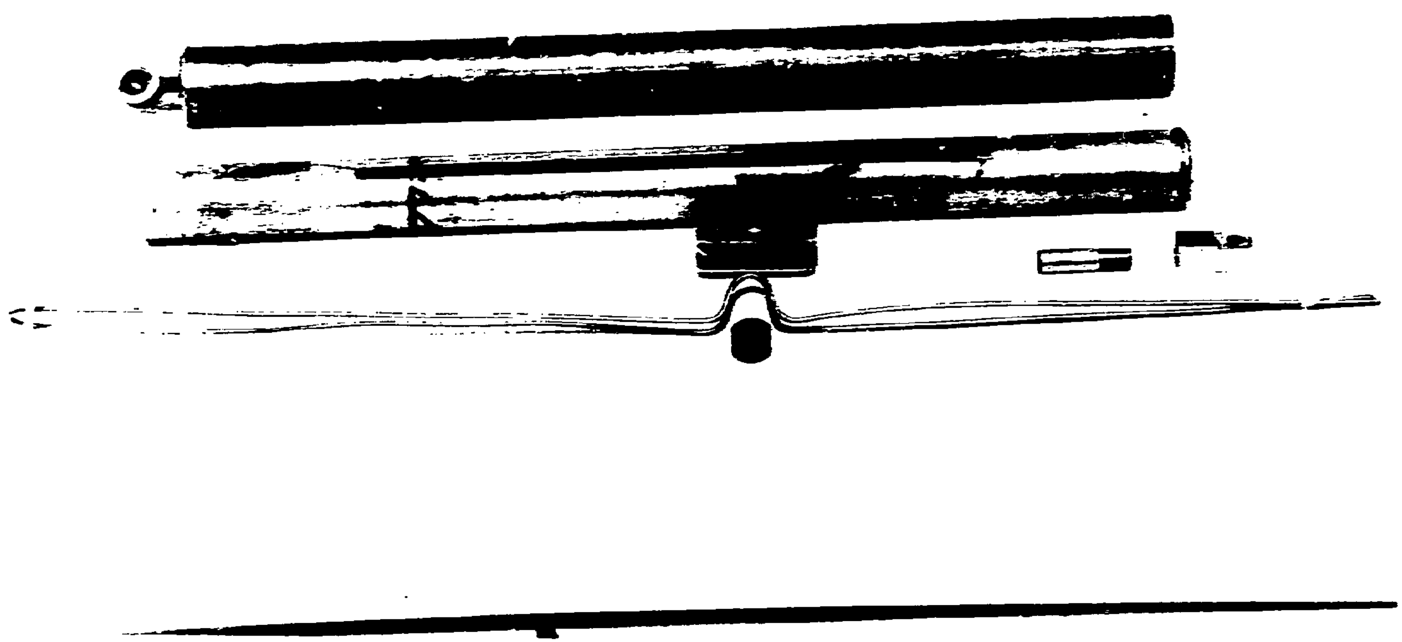

Figure 19. Disassembled wire-bending energy attenuator.

1. <u>Temperature</u>--The seat system was reviewed to determine whether materials and construction would withstand nonoperating exposure as well as deliver specified performance when subjected to the high and low temperature specified in Environmental Test Method 501, Procedures I and II, and Method 502 of MIL-STD-810. The following conditions can be experienced at high temperatures, according to the test procedures:

   - Permanent setting of packings and gaskets.

   - Binding of parts in complex constructions, due to differential expansion of dissimilar metals.

   - Discoloration, cracking, bulging, checking, or crazing of rubber, plastic, or plywood parts.

   - Partial melting and adhering of sealing strips.

   None of the materials or conditions are present in the troop seat design. The materials and construction used are not expected to be affected by the high temperatures. Of the materials used, polyester fabric and webbing are the materials most sensitive to heat; however, they withstand heat in excess of the test temperatures during the dyeing process without being affected.

   Conditions which could be experienced at low temperatures, such as differential contraction of metal parts, loss of resiliency of packings and gaskets, and congealing of lubricants would not be experienced on the troop seat because these materials are not present. The materials used in the troop seat will not be affected by the low temperatures.

2. <u>Sunshine</u>--The materials used in the troop seat system were reviewed with regard to degradation by sunshine as specified in Method 505, Procedure I, of MIL-STD-810. Polyester fabric and webbing used in the seat cover, support webbing and restraint system are the materials most likely to be affected by sunshine. Some fading of color can be expected; the degree of fading depends upon the color selected. Some material degradation would occur over the normal service life of the fabric and webbing, but sufficient safety margins are designed into the material so that system safety would not be compromised. The seat fabric has a strength of 700 lb. per in., for a 300-percent safety factor. The seat pan support webbing has a strength of 30,000 lb., allowing a 700-percent safety factor.

3. Humidity--The materials used in the troop seat system were reviewed to determine their resistance to the effects of exposure to a warm, highly humid atmosphere such as that specified in Environmental Test Method 507 of MIL-STD-810. Hydroscopic materials are generally sensitive to humidity. Moisture penetration can result in corrosion or swelling, which destroys mechanical properties. Hydroscopic materials other than the seat fabric and webbing, are not used in the troop seat. The polyester fabric and webbing will withstand humidity for prolonged periods without deterioration or loss of strength. Other seat materials do not appear to be sensitive to humidity.

4. Fungus--The troop seat materials were reviewed to determine if any contained nutrients to fungus. None of the materials listed in Environmental Test Method 508 of MIL-STD-810 are used in the seat construction and none of the materials used are suspected of containing fungus nutrients.

5. Salt Fog--Many of the materials used in the construction of the troop seat are subject to corrosion when exposed to salt fog such as that specified in Environmental Test Method 509 of MIL-STD-810. However, these materials are adequately treated and painted to resist the effects of salt fog.

6. Dust--The ability of the troop seat system to operate when subjected to a dust environment, such as that specified in Environmental Test Method 510 of MIL-STD-810, was reviewed. Mechanical operation of the seat is required only during a crash impact. At that time, the seat must move freely in the direction of the impact and be restrained by the load-limiting, extending energy attenuators. Moving parts consist of rod end bearings and energy attenuators. The yielding cable and wire-bending energy attenuator would not be affected by a coating of dust particles. The telescoping tube-type energy attenuator and the rod end bearings could be slightly affected by dust and dirt; however, these components are sealed to prevent entry of dust particles.

7. Vibration--The troop seat system was reviewed for areas which may be subject to fatigue, failure, or malfunction as a result of vibration similar to that specified in Vibration Test Method 514, Procedure I (Parts 1, 2, and 3), of MIL-STD-810. One area of the seat which was suspected of being critical under vibration was the point where the vertical energy

attenuator wire was threaded through the thin channel section of the toggle latch. This area was redesigned and the potential vibration condition removed. One other area suspect of being a problem was the rolling helical wire energy attenuator. This device consists of telescoping aluminum tubes with wire wrapped between the tubes. It is possible that vibration will cause the wire to peen ridges inside the tube; and the result would be that the wire would not roll as designed for energy attenuation. This device, however, did not function properly as an energy attenuator, so an alternate design was recommended.

8. Mechanical Shock--The troop seat system was reviewed for areas which could fail if subjected to the mechanical shock environment normally encountered in handling and transportation. The environment specified in Shock Test Method 516 of MIL-STD-810 was considered. The seat is designed to withstand crash impact loads and when the seat is packaged for shipment in accordance with the troop seat military specification, it can be expected to withstand drops of the severity specified.

MAINTAINABILITY ANALYSIS

Review of the details and installation procedure for the crashworthy troop seat reveals no major maintenance problems. Standard hardware is used at attachment points and no special tools are required for maintenance. The seat design employs quick-disconnect devices at key attaching points which permit rapid and efficient seat removal or stowage by one man (Reference 5). Replaceable components (energy attenuators, cables, headrests, and seat fabric) are accessible and replaceable at organizational level.

RELIABILITY ANALYSIS

The crashworthy troop seat is similar to a crashworthy gunner's seat assembly, which was subjected to an analysis of assembly and component failure modes and their effects. Each mode of failure was evaluated to determine its criticality with respect to safety, mission accomplishment, component removal, or corrective maintenance demand. These data were documented on Failure Mode Effects and Criticality Analysis forms (FMECA) in Reference 7.

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[7] Reilly, M.J., Crashworthy Helicopter Gunner's Seat Investigation, Boeing Vertol Company, Philadelphia, Penna.; USAAMRDL Technical Report 74-98, Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, January 1975, AD A005563.

The crashworthy troop seat assembly is expected to have 0.030 failures per 1,000 component hours. However, most of these failures are expected to be caused by abuse and handling during seat removal, storage, and installation, and would be repaired before use by troops or before the assembly was required to operate in a crash.

Strength

A stress and load analysis was performed for the troop seat and is discussed in Reference 5. This data, in conjunction with the component tests and modifications discussed in this report, was considered to be sufficient to verify that the troop seat had sufficient strength to undergo static testing.

TASK I SUMMARY

In the performance of component testing, several deficiencies in the design of seat components were determined. Redesign of the malfunctioning components and retesting resolved these deficiencies. Basic seat structure was analyzed through load and stress analysis. The operational suitability of the seat construction and its materials was assessed by further analysis.

On the basis of these tests and analyses, the crashworthy troop seat was anticipated to function as required in a crash environment and was considered to be ready for verification of these functions by static testing.

CRASHWORTHY TROOP SEAT TESTING - TASK II

TASK II - REQUIREMENTS

The required Task II effort was as follows:

- The fabrication, modification, and assembly of forward- and aft-facing seat systems in accordance with the approved detail design developed in Task I.
- The preparation of seat system and test fixtures to perform static testing in accordance with the approved static test plan (Appendix B).
- The performance of static tests on seat systems in accordance with the approved static test plan.
- The analysis of data obtained in static tests and verification of the capability of the forward- and aft-facing seat systems tested to meet the static performance criteria contained in paragraph 4.5.3.1 of the proposed Military Specification, Seat, Helicopter, Troop.
- The performance of detailed redesign of those troop seat system components that fail to meet the static test requirements of paragraph 4.5.3.1 of the specification.
- The preparation of a test plan for dynamic testing forward- and aft-facing seat systems in accordance with the specification (Appendix C).

Each of these areas is discussed in this report in the order listed above.

FABRICATION AND MODIFICATION OF SEAT SYSTEMS

The crashworthy troop seat test specimens required for this test program are forward- and aft-facing configurations. The basic forward-facing seat concept was developed under Contract DAAJ02-72-C-0077 (Reference 5). This concept required modification, and a similar rear-facing seat configuration was developed. Both types of seats are similar in construction. The seat plan, constructed of tubing and covered with fabric, is suspended in a cantilever fashion (Figure 1). The back, a tubular compression member in combination with a webbing tension member, forms a truss which supports the seat pan. A fabric auxiliary back is provided along the plane of the tension webbing. A flap in the auxiliary back is removable, uncovering a pocket which will accommodate a combat pack.

The seat pan is maintained in a near level attitude during stroking by the cantilever suspension system. Stability in the longitudinal direction is maintained by energy attenuator struts attached diagonally from the front of the seat pan to the floor on forward-facing seats, and reversed on aft-facing seats. These struts are free to rotate downward without stroking during vertical crash impact conditions. Lateral stability is accomplished by crossed cables at the front and back of the seat.

Energy attenuation is provided in the vertical, forward, and lateral directions. A compact wire-bending energy attenuator is used for vertical impact loads. The seat is capable of stroking vertically 14-1/2 in. Longitudinal attenuation is accomplished during forward crash impact by the combined action of the vertical attenuators and the diagonal strut attenuators under the seat.

These tubular diagonal strut attenuators incorporate a wire-bending roller system inside telescoping tubes. The load-limiting effect is produced by wire bending and unbending as it passes over rollers. This device is capable of tension or compression loading. Lateral-impact loads are attenuated by the crossed cables, which yield under crash loads permitting 6 in. lateral seat stroke. Seat freedom of movement in all three axes is permitted during a crash by ball-type rod end bearings which attach the stabilizing struts to the seat pan. The attenuating struts and energy-attenuating cables are permitted to rotate at the floor by the four quick-disconnect fittings attached to the floor studs.

Lap belt anchor fittings are connected to the seat pan tube on both sides of the seat. Two shoulder harness reels, permitting full and independent strap retraction, are attached to the tubular seat back. Guides are provided to position the shoulder straps. A low-elongation polyester webbing is used as the strap material.

A total of ten seats, five forward-facing and five aft-facing, were required for this program. One of the seats was allocated to an aircraft crash test program (Reference 8), five for static testing, and four for dynamic testing. Eight seats, fabricated during the program described in Reference 5, were capable of being modified to meet the static test requirements. Modifications were required, as a result of component testing

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[8]Singley, G. T. III, "Full Scale Crash Testing of a CH-47C Helicopter", AHS Paper No. 1084, presented at 32nd Annual National Forum of the American Helicopter Society, Washington, D.C., 10-12 May 1976.

conducted in Task I, to replace parts known not to meet the strength requirements when the seats were used as mock-ups, and for conversion to the aft-facing seat configuration. The changes made to the seats are as follows:

- Convert two 2-man seats to four 1-man seats.
- Convert three forward-facing seats to aft-facing seats.
- Replace mock-up restraint systems with adequate-strength restraint systems using low-elongation polyester.
- Fabricate new fabric assemblies using polyester fabric to replace the nylon fabric used on the mock-up seats.
- Fabricate two new aft-facing seats.
- Fabricate new parts for the toggle latch.
- Rework existing parts of the toggle latch and reassemble.
- Fabricate vertical wire-bending attenuators having a new configuration.
- Fabricate tubular diagonal-strut attenuators conforming to the design developed in Task I.
- Rework and proof-test vertical hold-down cables.

STATIC TEST PREPARATION

A test fixture was designed and fabricated to support the seat test specimens as they would be supported in the aircraft (Figure 20). The fixture was designed to support the seat under test load application without deflecting. Provisions were made for floor attachments and ceiling attachments. The floor attachments were mounted on members which could be warped to produce a 10-degree pitch on one side and a 10-degree roll on the other side. Standard floor stud pans were used at the floor to which the floor quick-disconnect attachments could be connected.

The test fixture was designed to be adaptable for use in testing forward- or aft-facing seats and to orient the seats for the various angles of impact force application. The test fixture was quickly adaptable to installation of the forward- or aft-facing seats. Force application angles

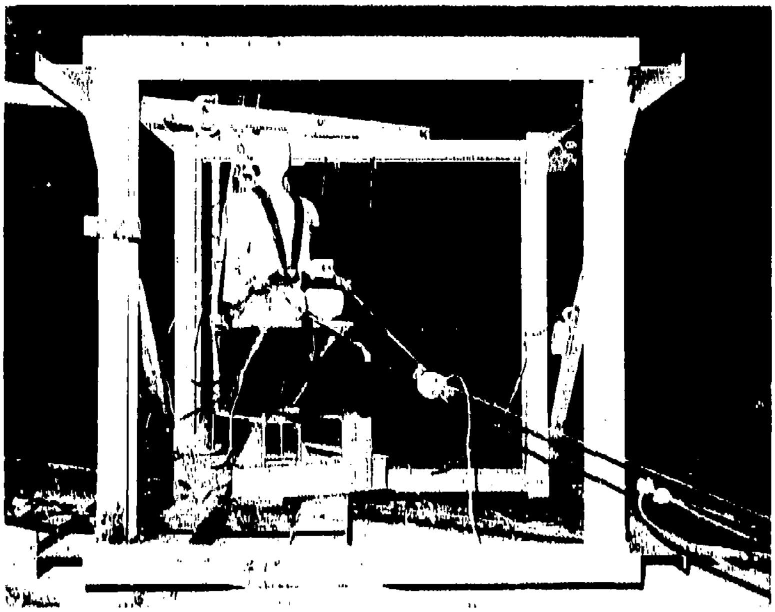

Figure 20. Static test fixture.

were variable by horizontal rotation of the fixture or by tilting the complete fixture, or a combination of both.

STATIC TEST REQUIREMENTS

The forward-facing seats were required to be subjected to forward and combined forward, lateral, and vertical loading. Tests were performed in accordance with the approved test plan (Appendix B). The sixth seat, a forward-facing seat, was tested with successful results in the CH-47C crash test performed jointly by the Eustis Directorate, NASA-Langley Research Center, and Boeing Vertol (Reference 8).

STATIC TESTS AND DATA ANALYSIS

A total of six static tests were performed using five seats. Four tests were performed using a forward-facing seat configuration and two tests were performed using an aft-facing seat configuration. Some retesting was necessitated by component failures.

Test 1 - Forward-Facing Seat, Forward Load

A forward-facing seat configuration was installed in the test fixture, suspended by two wire-bending energy attenuators at the ceiling and connected by four quick-disconnect studs to the floor (Figure 21).

The floor studs, mounted in standard recessed floor pans, were attached to a floor-warping device which was actuated before testing (Figure 22). The test fixture was actuated from a flat floor configuration (Figure 23) to a 10-degree pitch-up on one side and a 10-degree roll on the other (Figure 24).

A 95th percentile aluminum body block was installed in the seat and restrained by a four-point lapbelt shoulder harness system (Figure 20). Seat loading was accomplished by attaching a cable between the body block and a hydraulic cylinder. The cable was attached to a fitting on the body block at the representative center of gravity of a 95th percentile occupant. A 50-foot-long cable was used to minimize the load application angle change as the seat stroked vertically (Figure 20). A minimum loading of 15G was to be applied.

Loading was applied gradually to the body block by the hydraulic cylinder. Force versus deflection was recorded by the instrumentation. Excessive deformation began at about 60 percent of design load and the curve moved into the unacceptable base area of the Military Specification force deflection curve (Figure 25). The excessive deflection was attributed to the yielding of the anchor plates attaching

Figure 21. Forward-facing seat, forward loading.

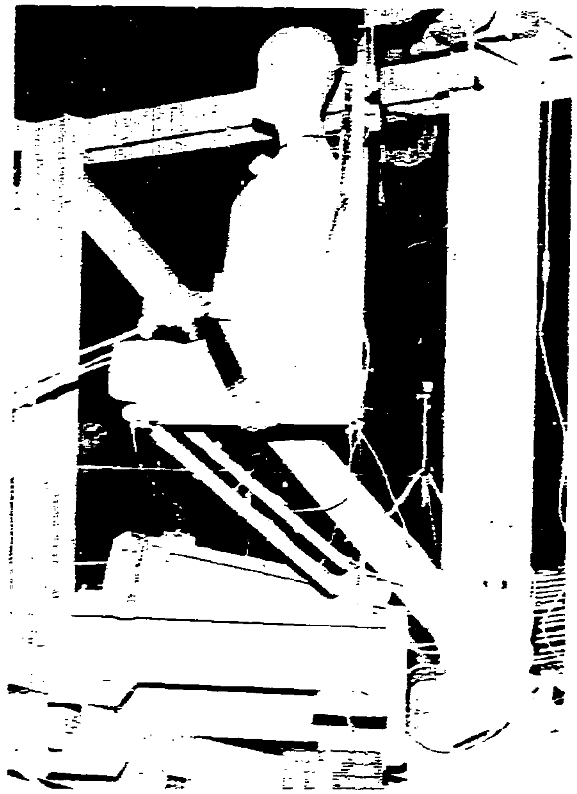

Figure 22. Pre-test, flcor warped.

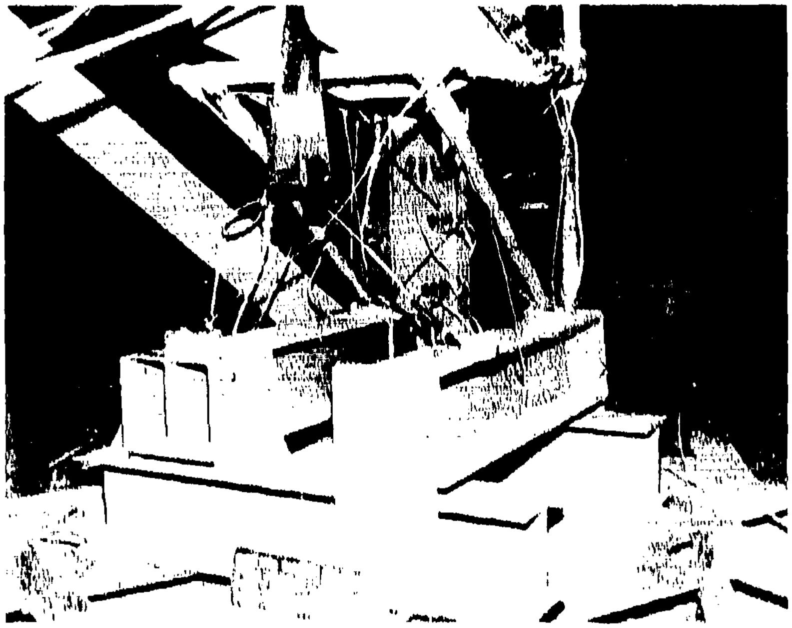

Figure 23. Floor unwarped.

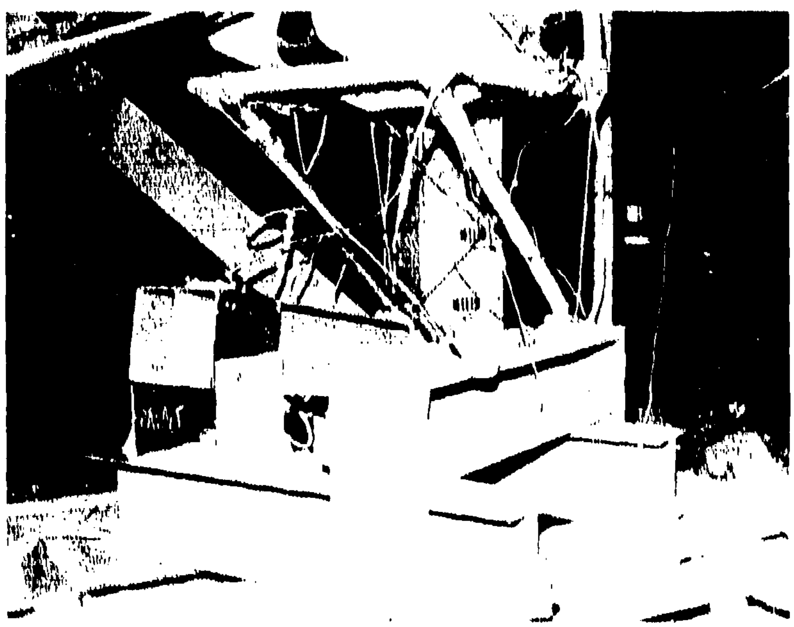

Figure 24. Floor warped.

the seat pan support straps to the seat back and to an under-strength vertical energy attenuator. Failure of the anchor fittings on both sides of the seat occurred at 90 percent of design load (Figure 25).

Stress concentration through the slotted area caused tensile yielding of the material adjacent to the slot (Figure 26). Failure of the strap attachment caused the front of the seat pan to drop approximately 20 degrees. Further dropping was prevented by shoulder straps and the lapbelt attachment to the seat pan (Figure 27).

The seat was undamaged as a result of the anchor fitting failure. The anchor fittings were replaced with strengthened parts, and the 0.100-in.-diameter wire elements in the vertical attenuators (which had stroked 3.5 in.) were replaced with 0.110-in.-diameter wire to increase the stroking load. A retest was scheduled for the following day.

<u>Test 1A - Forward-Facing Seat, Forward Load</u>

The modified seat was installed in the test fixture in a manner similar to that in Test 1. Load was applied to the body block by the hydraulic cylinder. Loading was increased gradually and 135 percent of the design stroking was reached. The force-deflection curve remained inside the boundaries of the military specification limitations. A failure occurred after 4.5 in. of longitudinal deformation and was within 8 percent of the acceptable failure line (Figure 28).

Failure occurred at the lapbelt attachment to the side of the seat pan. A long, unsuitable bolt had been substituted for the original lapbelt attachment bolt to permit installation of a strain-gaged adapter fitting (Figure 29). The adapter was placed on the threaded portion of the bolt and the bolt failed through the threads. All of the load shifted to the remaining lapbelt side, causing the seat to rack (Figure 30). This caused the diagonal attenuator strut to be torn from the seat pan attachment (Figure 31), and cracks to occur in the seat back tubes (Figure 32).

The vertical attenuators stroked 4.3 in. before failure occurred. No stroking of the diagonal-strut attenuators was measured.

Although this test resulted in failure, it was determined that the vertical attenuator stroking load was satisfactory, while the diagonal-strut attenuator stroking load should be reduced. Tests were conducted on the struts to verify the 1,300-lb. design load and they checked out within tolerance. Stroking load was reduced by disassembling the units and

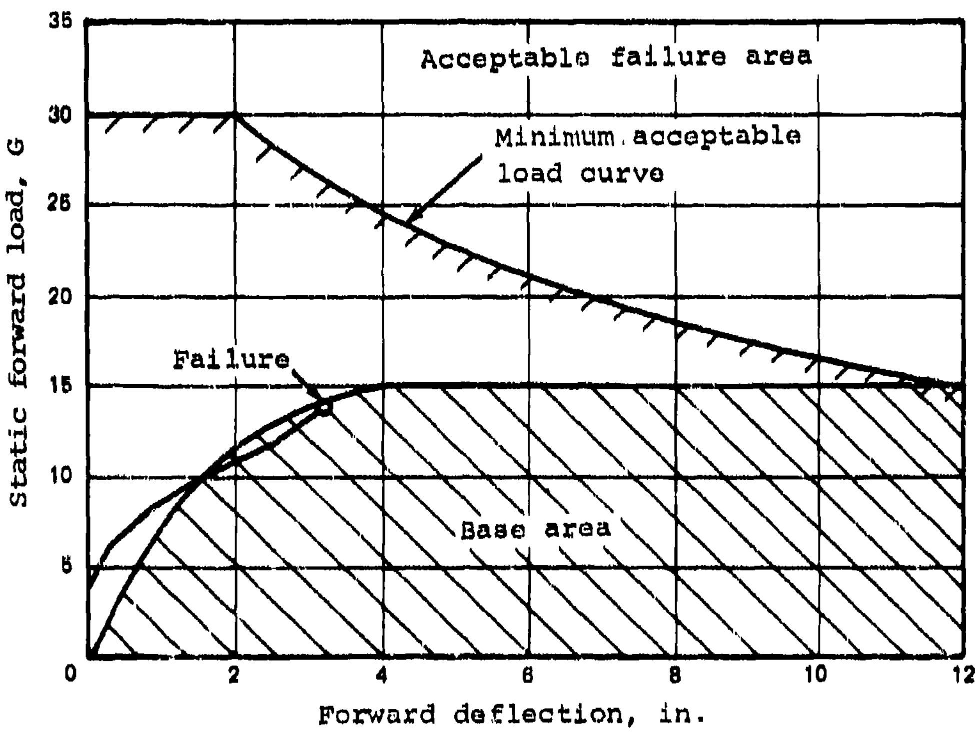

Figure 25. Test 1, forward-facing seat, forward load/deflection.

Figure 26. Failed strap anchor.

Figure 27. Post-test seat condition.

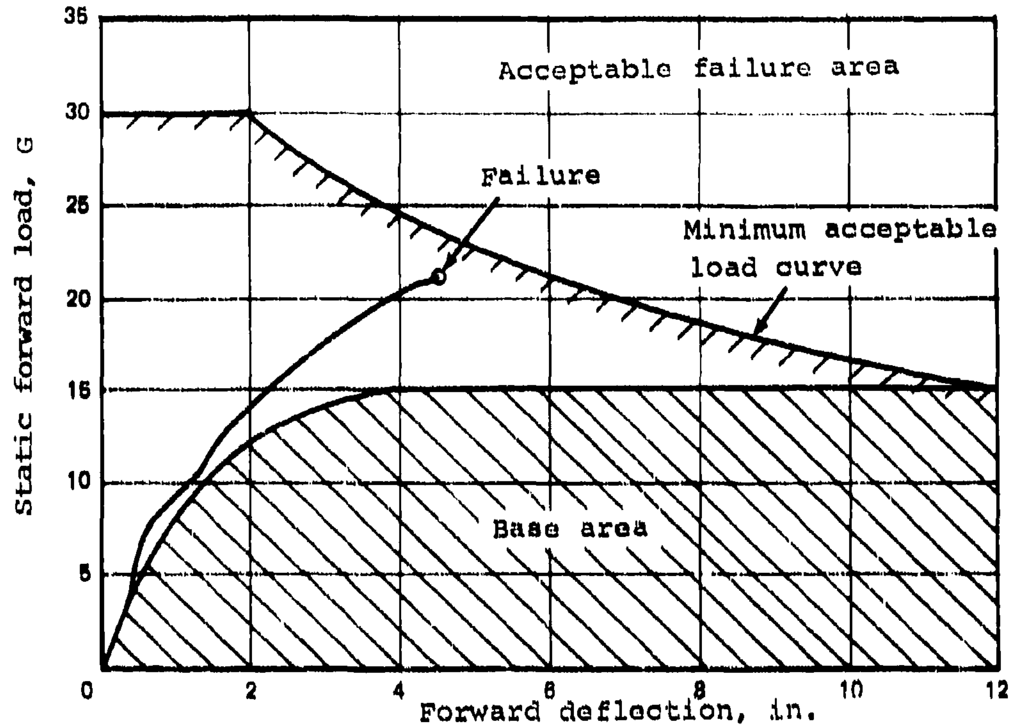

Figure 28. Test 1A, forward-facing seat, forward load/deflection.


Figure 29. Lapbelt anchor adapter.

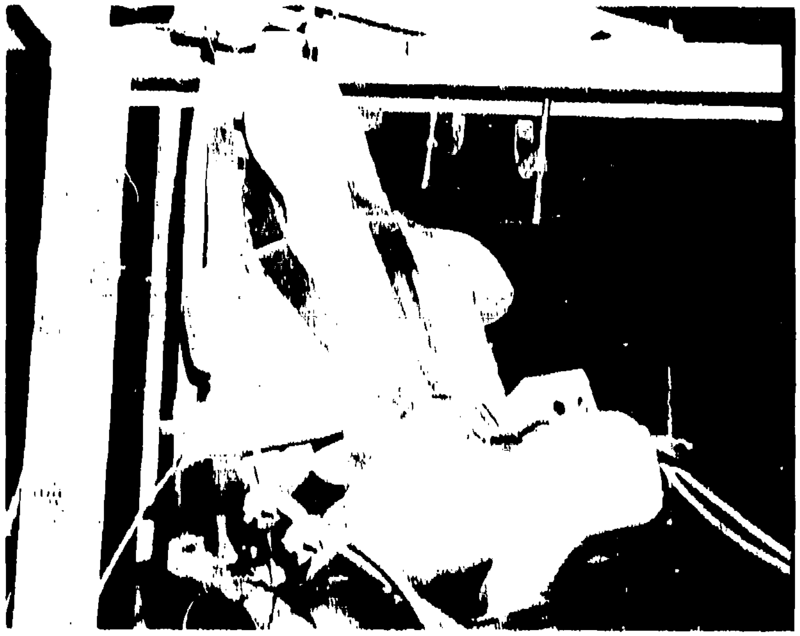

Figure 30. Post-test racked position.

Figure 31. Failed strut attachment fitting.

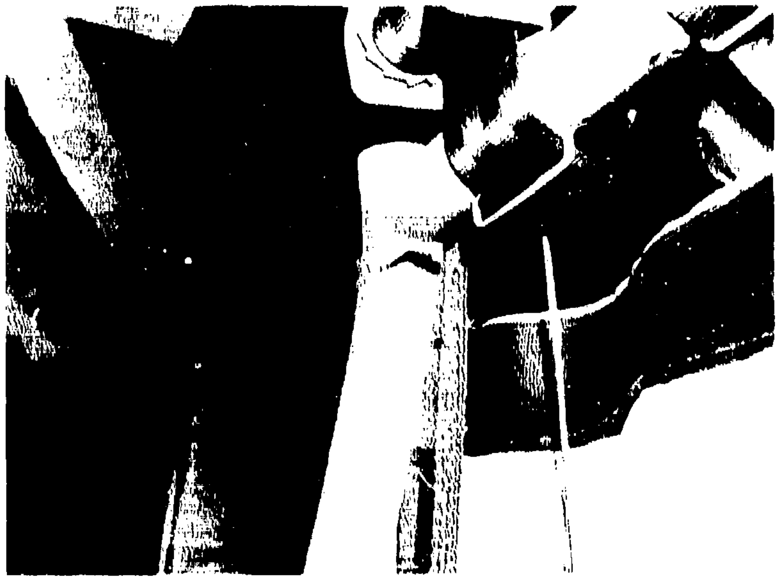

Figure 32. Seat back tube crack.

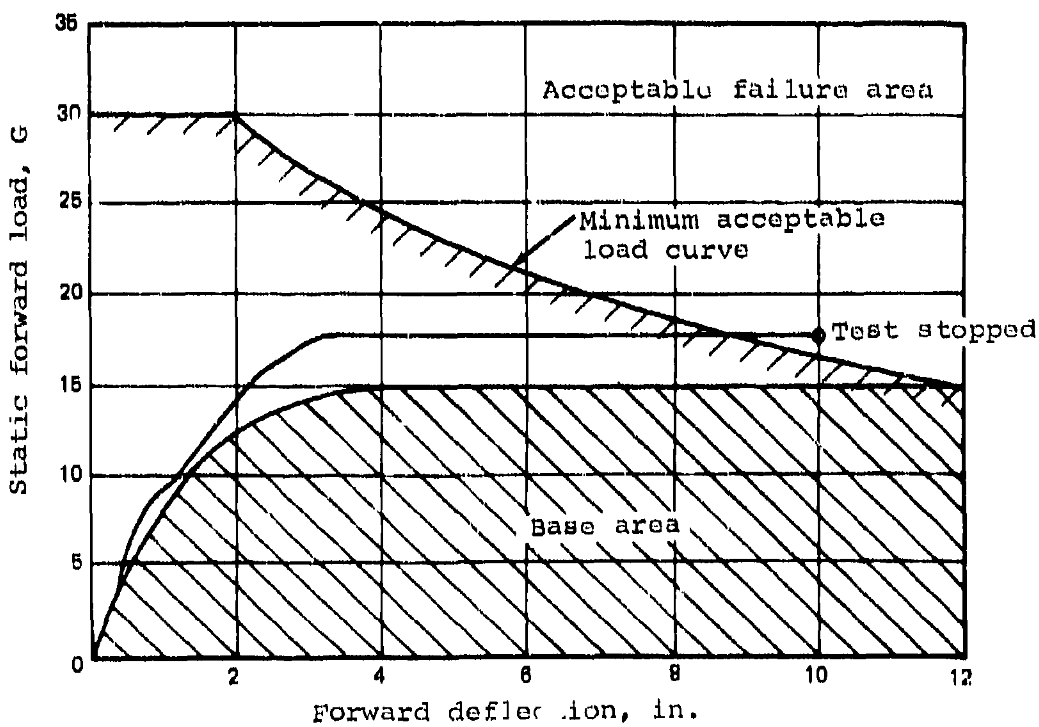

Figure 33. Test 1B, forward-facing seat, forward load/deflection.

elongating the holes in the plates which support the trolley rollers. Offsetting the rollers in this manner reduces the bend angle of the wire as it passes over the rollers. The load was reduced to 1,100 lb.

Test 1B - Forward-Facing Seat, Forward Load

A second retest was conducted, using a seat which had been designated for aft-facing three-axis combined loading. The forward-facing test was considered to be more critical than the aft-facing test because three aft-facing seat tests were to be performed, compared to only two forward-facing seat tests. The seat was modified to convert it to a forward-facing seat and to install new vertical and diagonal-strut energy attenuators having the revised stroking load values.

The modified seat was installed in the test fixture in a manner similar to that in Test 1. Load was applied to the dummy. Some difficulty was experienced with a faulty toggle latch; the latch was replaced and the test continued.

The vertical attenuators began stroking first, as anticipated, due to the bowstring effect. As the angle of the attenuators increased because of seat back movement, the forward load required to cause the vertical attenuators to stroke also increased. The forward load increased until the stroking load threshold of the diagonal-strut attenuators was reached. At this point, the seat was in balance and both the upper and lower attenuators were stroking. The force deflection curve produced by the action of the attenuators was within the limits of the curve specified in the proposed Military Specification, Seat, Helicopter, Troop (Figure 33). The G level increased gradually until the seat displaced forward approximately 3 in. At this point, a constant level of 18G was maintained as the seat stroked forward the remainder of the required 10 in., at which point the test was stopped.

The instrumentation recorded loads in the lapbelt, shoulder straps, and vertical and diagonal energy attenuators and load applicator. String potentiometers measured deflections of the seat in the vertical and longitudinal directions and was used along with the applicator load to produce the curve in Figure 33.

Restraint system loads were divided fairly equally between each shoulder strap and each side of the lapbelt (Figure 34). Data on the shoulder strap load was lost at the 1300-lb level. Load data on the vertical attenuators was not reliable due to bending of the fittings to which the strain gages were attached. Diagonal-strut attenuators were designed to stroke at 1100 lb. The instrumentation data showed the load to rise

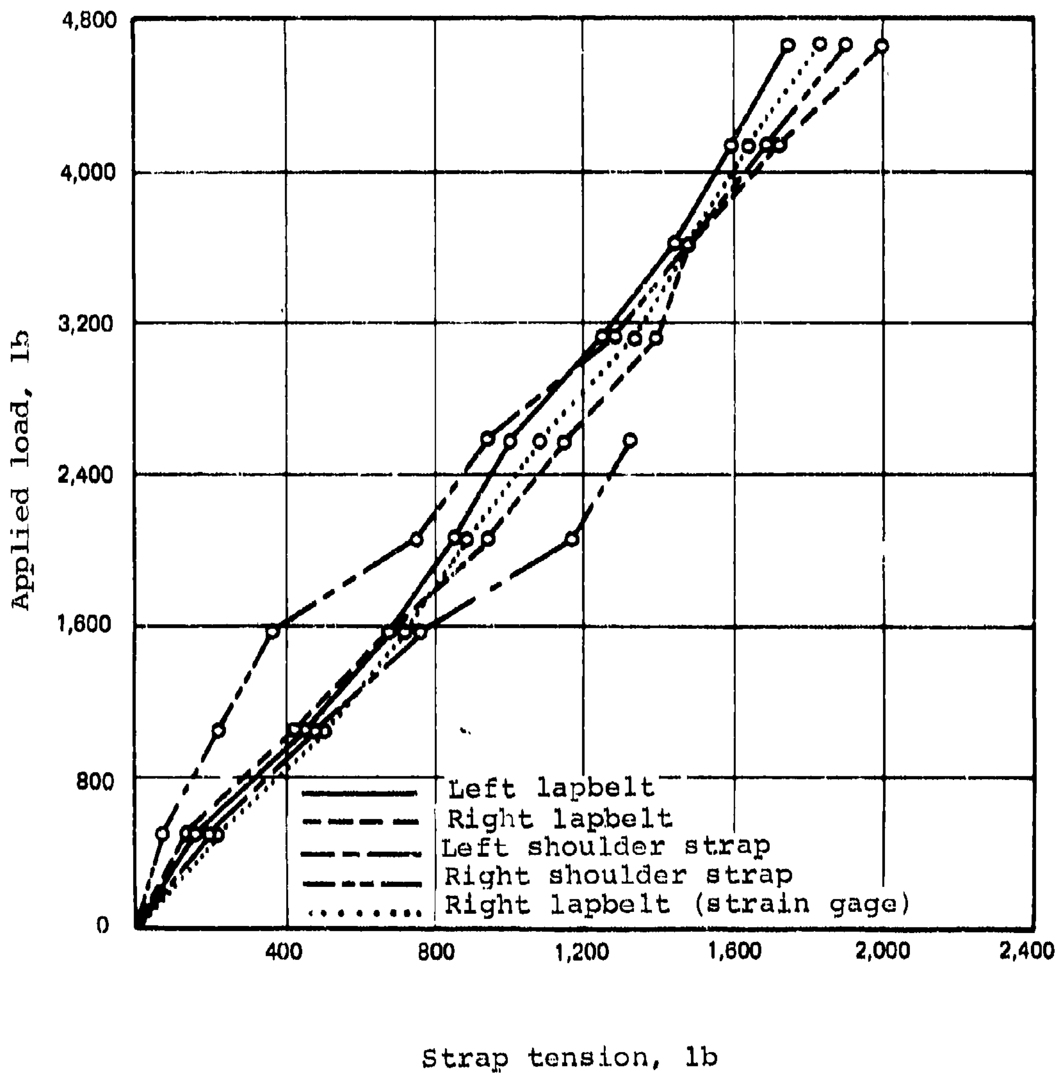

Figure 34. Test 1B, lapbelt and shoulder strap loads.

to approximately that level, at which point the attenuators began stroking. This relieved the load on the hydraulic actuator and momentarily caused the load curve to drop, producing a false reading which would not exist under a dynamic situation.

After the test, a visual inspection of the seat was made. There were no failures of the seat structure or fabric (Figure 35). Some deformation was observed in the seat pan side tubes which had bowed up 0.5 in. in the center (Figure 36). The vertical attenuators were found to have stroked 6.75 in. (Figure 37) and the diagonal-strut attenuators stroked 3.62 in. (Figure 38).

The test conclusions are that the results were highly successful in meeting all test objectives.

Test 2 - Forward Load on Aft-Facing Seat

An aft-facing seat configuration was installed in the test fixture, suspended by the two wire-bending attenuators at the ceiling and connected to the floor quick-disconnect studs at four places (Figure 39). The test fixture had been rotated 180 degrees from the Test 1 position. The diagonal-strut attenuators had been reworked to reduce the stroking load to 1,000 lb, 100 lb below the attenuators used in Test 1B.

A 95th percentile aluminum body block was installed in the seat and restrained by a four-point lapbelt shoulder harness system (Figure 39). The restraint system was not instrumented because the loading was toward the seat back and the restaint system received no load. Seat loading was accomplished by attaching a cable between the body block and a hydraulic cylinder. The load was applied effectively through the center of gravity of the body block by using a cable loop attached to fittings at each side of the body block (Figure 39). A minimum loading of 15G was to be applied.

Loading was applied gradually to the body block by the hydraulic cylinder. Force versus deflection was recorded by the instrumentation. Initial application of the load caused the seat to deflect backwards with little resistance, because the attachment of the toggle latch to the ceiling was at the same angle with the back as for forward-facing seats. This deflection caused an intrusion into the base area of the force deflection curve (Figure 40). As the angle of the toggle latch reversed, seat deflection decreased until a 10G force was applied, raising the curve out of the base area.

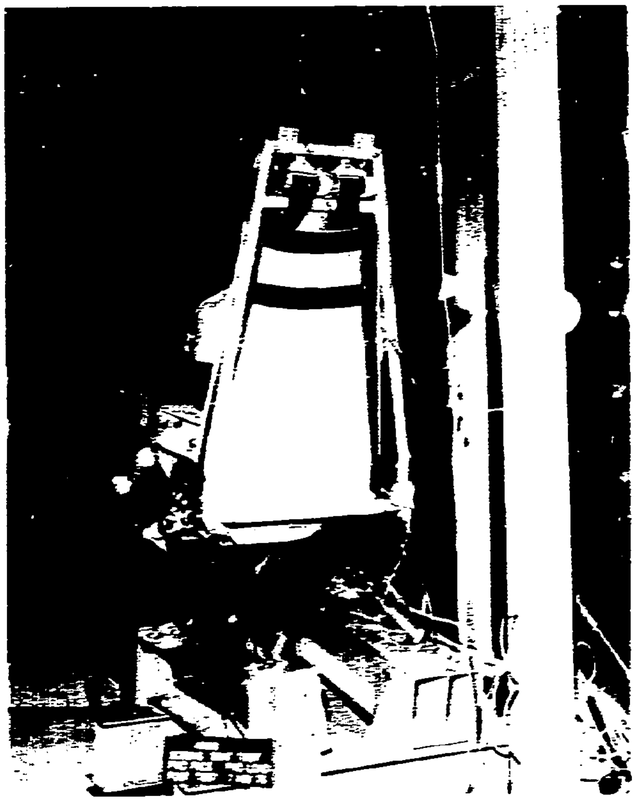

Figure 35. Post-test seat condition.

Figure 36. Bowed side tubes.

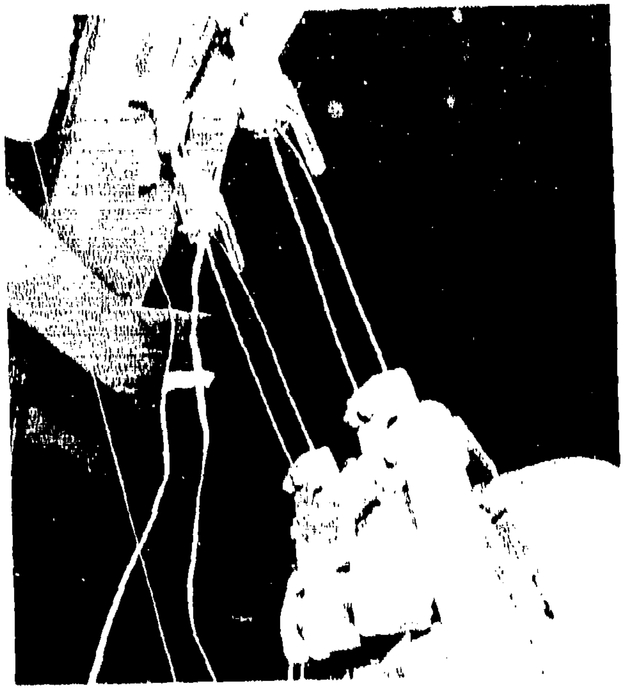

Figure 37. Stroked vertical attenuators.

Figure 38. Stroked diagonal attenuators.

Figure 39. Pre-test aft-facing seat, back loading.

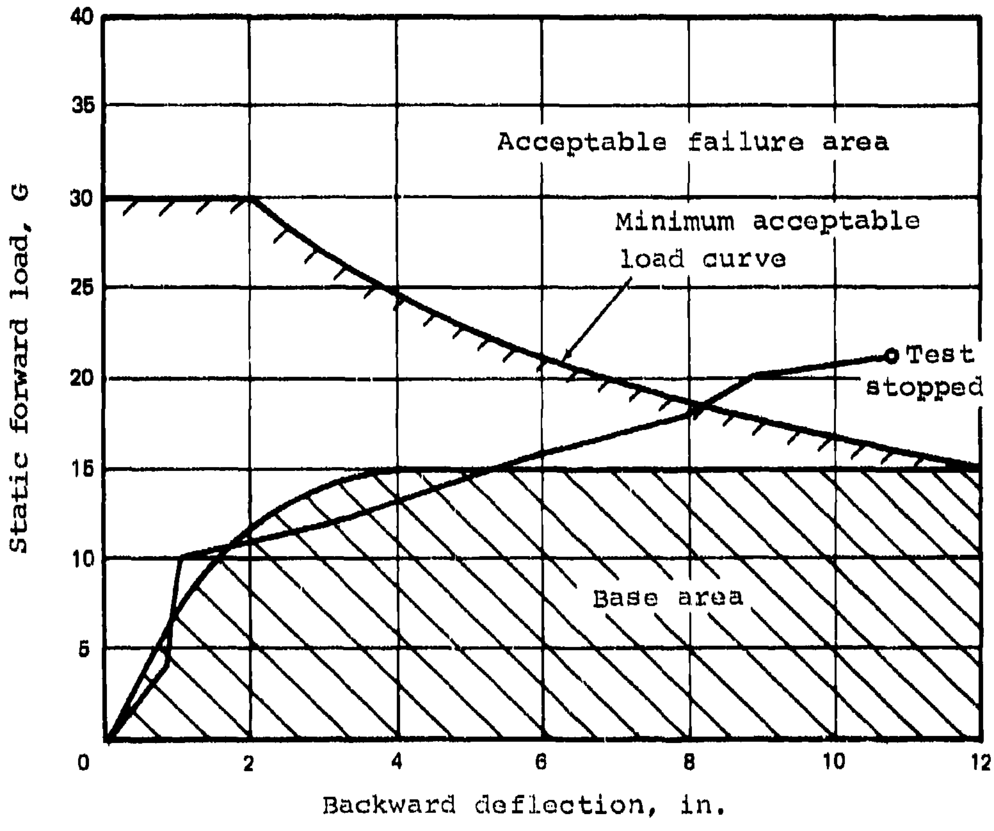

Figure 40. Test 2, aft-facing seat, backward load/deflection.

The initial deflection due to toggle-latch reversal also caused the angle of the diagonal attenuator strut to decrease in relation to the floor. The reduced angle, and the fact that the attenuator stroking load had been reduced below that of the Test 1B attenuators, caused premature stroking. This again caused a second slight intrusion into the base area to the extent of approximately 2G (Figure 40). The force/deflection curve soon rose out of the base area and above the minimum failure area line. The test was stopped when 11 in. of deflection had occurred.

An inspection of the seat was made after the test. No structural or fabric failures were found (Figure 41). Upper attenuators were found to have stroked 7 in. (Figure 42), and the diagonal-strut attenuator stroked 6.4 in. (Figure 43).

The test conclusions are that the results were satisfactory. Improvements can be achieved by relocating the upper seat attachments for aft-facing seats to reduce the initial deflection. In addition, the diagonal-strut stroking load should be maintained at the same level as that used in Test 1B. This will raise the load deflection curve sufficiently to prevent intrusion of the base area.

Test 3 - Aft-Facing Seats, Lateral Load

An aft-facing seat configuration was installed in the test fixture, oriented 90 degrees to the pull force. The seat was suspended from the ceiling support beam by two wire-bending attenuators and was connected to the floor quick-disconnect studs at four places (Figure 44). The load was transferred through the body block to the restraint system attached at the side of the seat and at the top of the seat back. A minimum loading of 10G was to be applied.

Loading was applied gradually by the hydraulic cylinder. Force versus deflection was recorded by the instrumentation. The force was increased until 86 percent of the design stroking load was reached. At this point, the welded connection of the tubing at the front corner of the seat pan failed (Figures 45 and 46). A soft weldable aluminum alloy tubing had been used in the construction of the seat pan, which contributed to the failure and allowed deformation of the seat, causing some intrusion into the base curve area (Figure 47).

The production version of the seat described in Reference 5 uses high-strength aluminum tubing and a forged aluminum corner fitting which is mechanically fastened. Such construction would be more rigid than the test model and would withstand higher loads. The intrusion of the force deflection curve into the base area close to the base curve and the occurrence of failure at 86 percent of design stroking load indicates

Figure 41. Post-test seat condition.

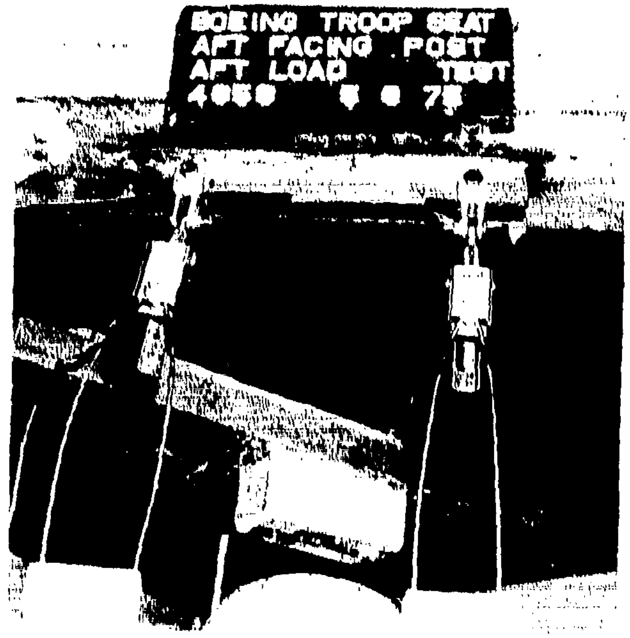

Figure 42. Stroked vertical attenuators.

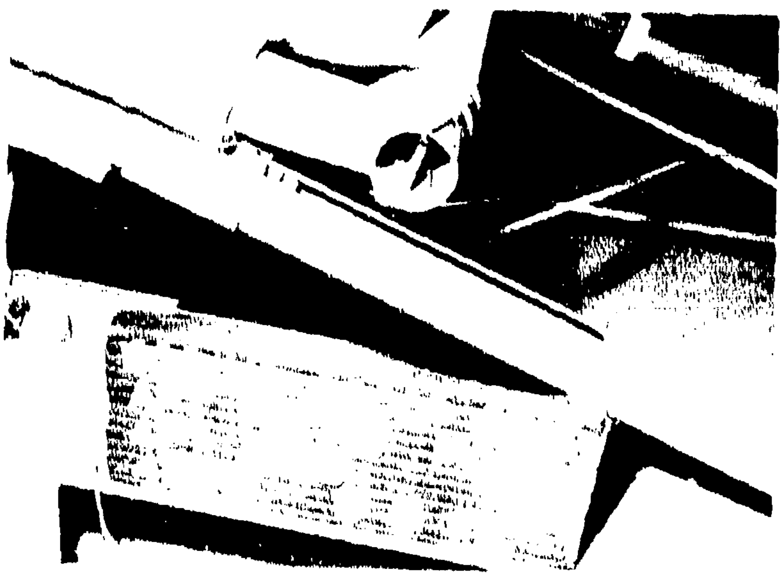

Figure 43. Stroked diagonal attenuators.

Figure 44. Pre-test aft-facing seat, side loading.

Figure 45. Post-test failed seat pan.

Figure 46. Failed seat pan corner.

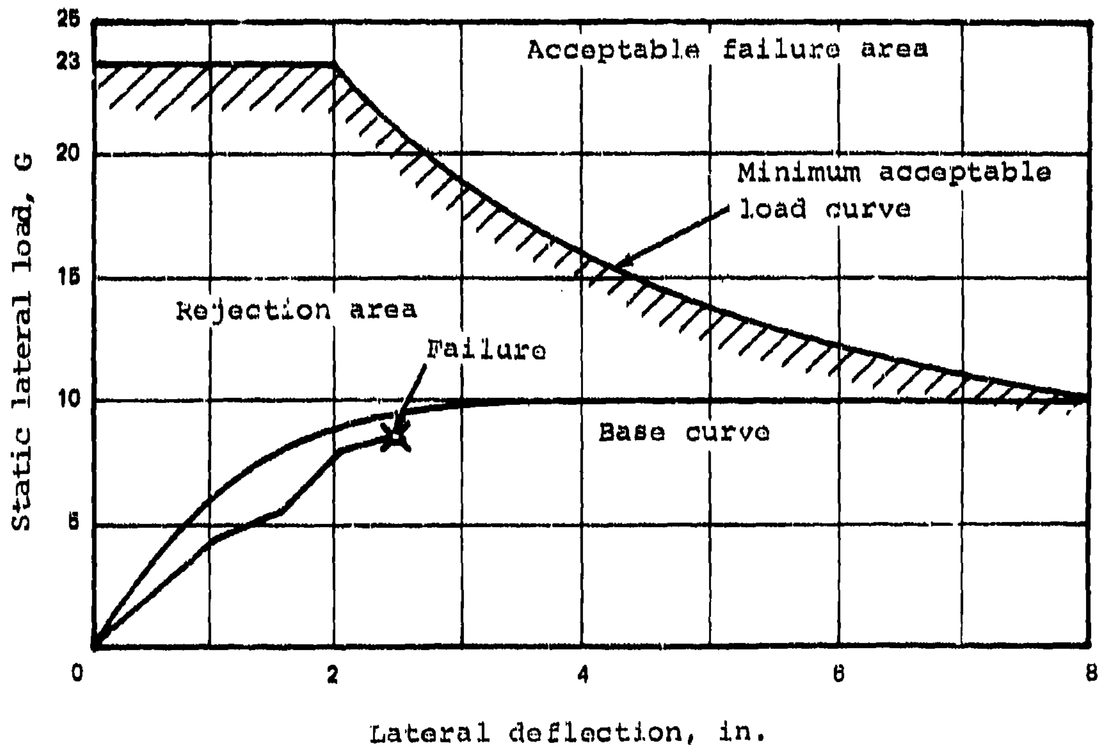

Figure 47. Test 3, aft-facing seat, lateral load/deflection.

that a small increase in stiffness and strength would put the force deflection curve into the acceptable area.

The instrumentation recorded lateral and vertical deflections of 2.5 in. at the time of failure. The excessive vertical deflection was due to yielding of the soft seat pan tube at the point where the deflection potentiometer was attached. Measurement of the vertical energy attenuators showed them to have stroked 0.5 in. The front diagonal cable had stroked 0.75 in. and the rear diagonal cable 1.2 in. Strain gage data from the attenuators was not reliable. Instrumentation data on lapbelt and shoulder harness loads shows a maximum of 1,050 lb on the lapbelt and 1,550 lb on the loaded left shoulder strap (Figure 48).

The test conclusions are that with minor improvements, the seat will meet the requirements for lateral loading. The seat remained stable during the loading sequence. There was no tendency for the seat to rotate or twist. All attenuators required to stroke were stroking at the time of failure. The force deflection curve and load at the time of failure were sufficiently close to the test objectives so that a slight increase in seat pan rigidity and strength will allow these objectives to be met.

Test 4 - Forward-Facing Seat, Combined Loading

A forward-facing seat was installed in the test fixture which was pitched up and yawed to simulate a three-axis crash load condition (Figure 49). The minimum loading to be applied was 14.5G downward, 15G forward, and 9G lateral. The seat was attached to the test fixture in the same manner as previous tests.

A 95th percentile aluminum body block was placed in the seat and restrained by a four-point lapbelt shoulder harness system. The seat was loaded by applying a load to the body block through a looped cable attached to fittings on each side of the body block (Figure 49). A resultant of the forward, lateral, and down loads was applied through the center of gravity of the body block. A minimum loading of 5,000 lb was to be applied.

Loading was applied gradually by a hydraulic cylinder. Force versus deflection was recorded by the instrumentation (Figure 50). The minimum design load was reached at 5 in. of forward deflection. The load continued to climb to 6,200 lb when the test was stopped at the point of 10 in. of deflection along the load axis. Most of the deflection was a result of the vertical attenuator stroking (Figure 51) and rotation of the diagonal-strut attenuators (Figure 52). The seat moved downward 6.3 in., forward 9 in., and laterally 4 in. Strain-gaged

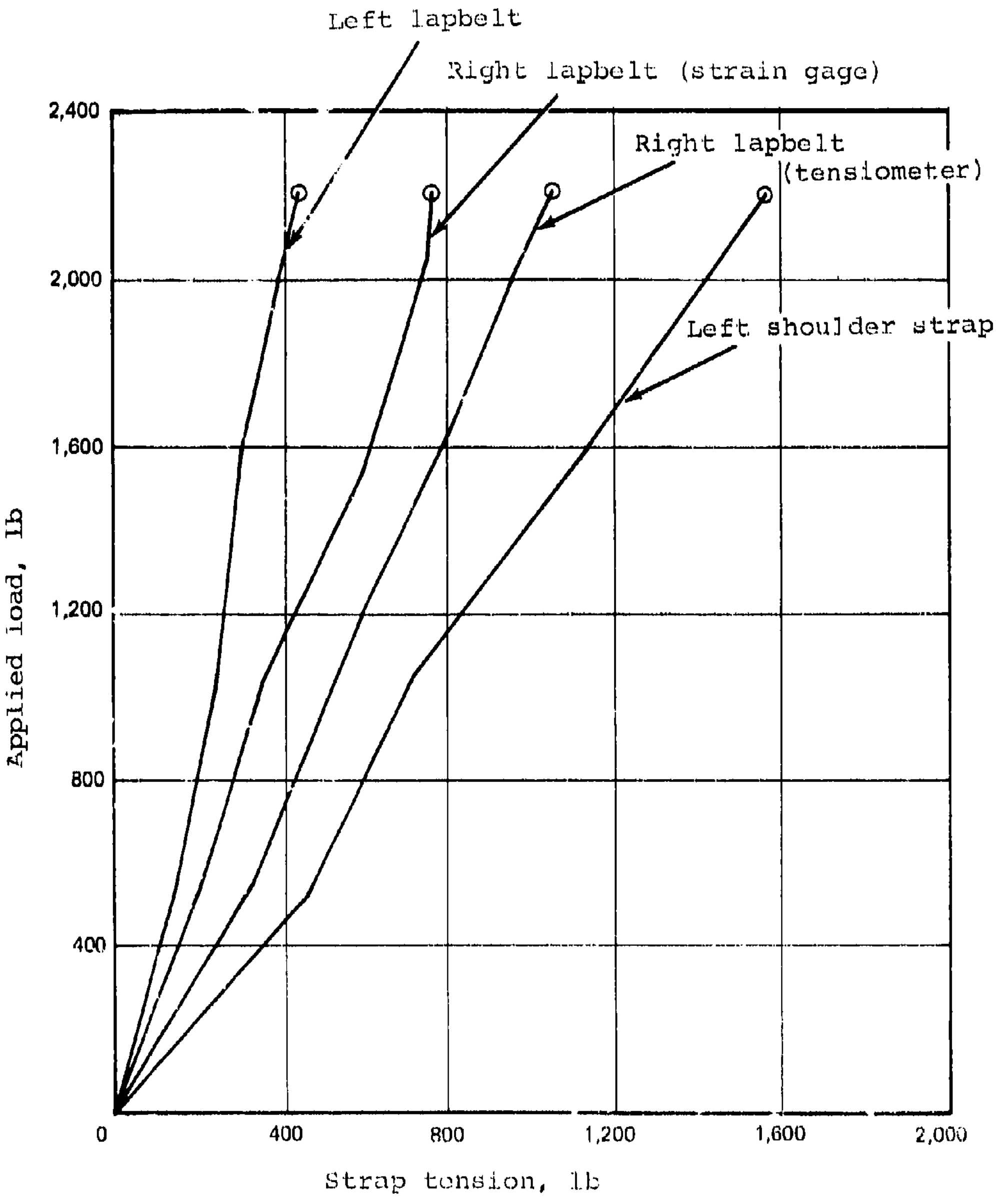

Figure 48. Lapbelt and shoulder strap loads.

Figure 49. Pre-test forward-facing seat, combined three-axis loading.

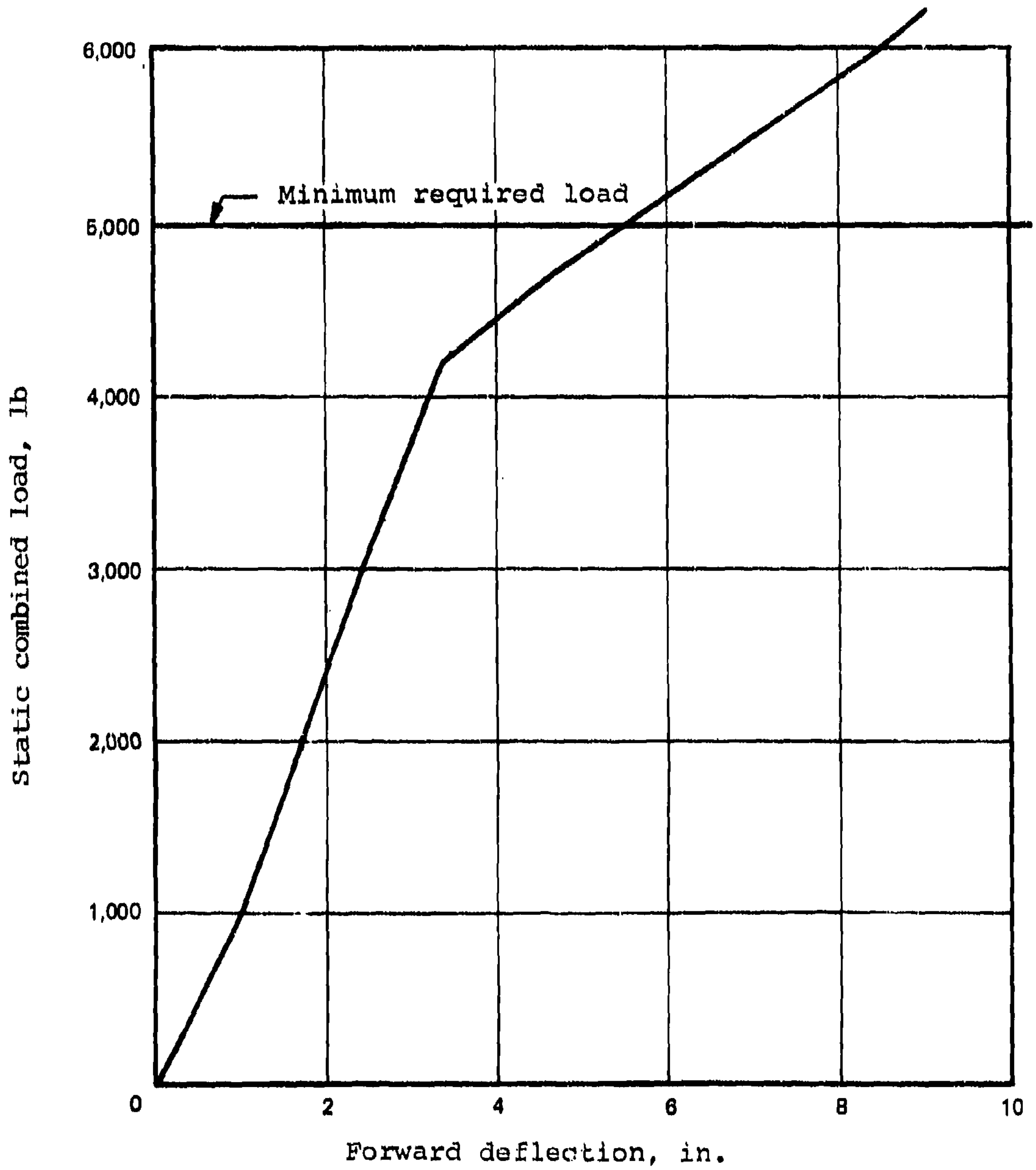

Figure 50. Forward-facing seat, combined triaxial loading, forward deflection.

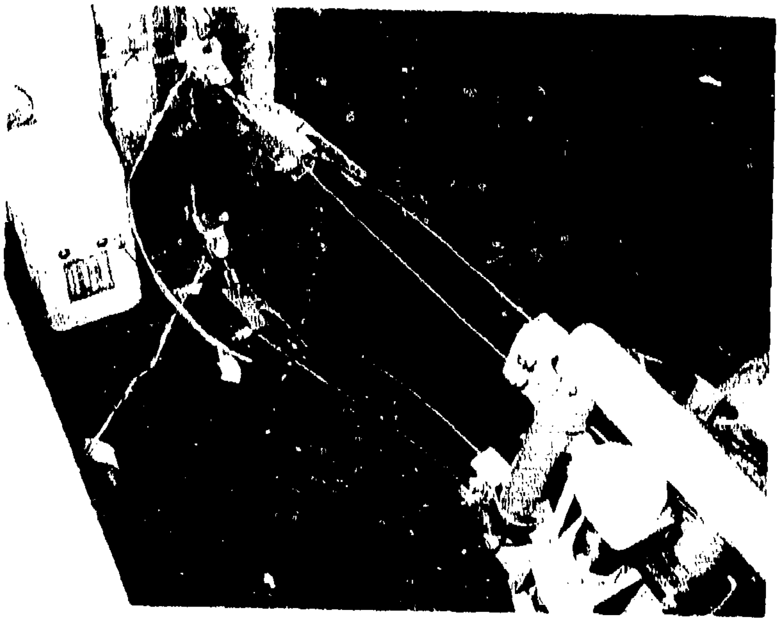

Figure 51. Stroked vertical attenuators.

Figure 52. Post-test seat condition.

data from the attenuators was not reliable. Data on the lapbelt shoulder strap shows a maximum load of 1,250 lb in the lapbelt and 1,505 lb in the left shoulder strap (Figure 53). Data on the right strap did not record.

Inspection of the seat showed that there were no structural failures or excessive deformations (Figure 51). The vertical attenuators were measured and had stroked 7.25 in. The diagonal-strut attenuators were measured; the right attenuator had stroked 0.25 in. in compression and the left 0.75 in. in tension.

The test conclusions are that the seat functioned satisfactorily and met all of the test objectives. Deflections at various force levels were considered to be well within reasonable limits for a troop seat.

SEAT DETAIL REDESIGN

In the performance of the static tests, some of the seat detail components were found to be unsatisfactory and some redesign was necessary. Items requiring design modifications were as follows:

- The support strap-to-seat anchor fitting.
- The vertical attenuator wire.
- The diagonal strut attenuator.
- The seat pan corner connection.

The anchor fitting was redesigned by increasing the gage from 0.063 to 0.080, and the area for inserting the strap was changed from a slot to a triangular hole. The triangular hole eliminates the stress concentration occurring at the ends of the slots.

The wire gage of the vertical attenuator was changed from 0.100 to 0.110 to increase the stroking load to 1450 lb and thereby raise the load deflection curve out of the base area.

The diagonal-strut attenuator stroking load was reduced from 1,300 lb to 1,100 lb to lower the stroking load and produce a balance with the vertical attenuator load. This reduction permits longitudinal stroking at a point just above the base area curve.

The seat pan corner connection design used for the test seats was necessitated because of cost and leadtime. A mechanically connected corner, using high-strength aluminum tubing as

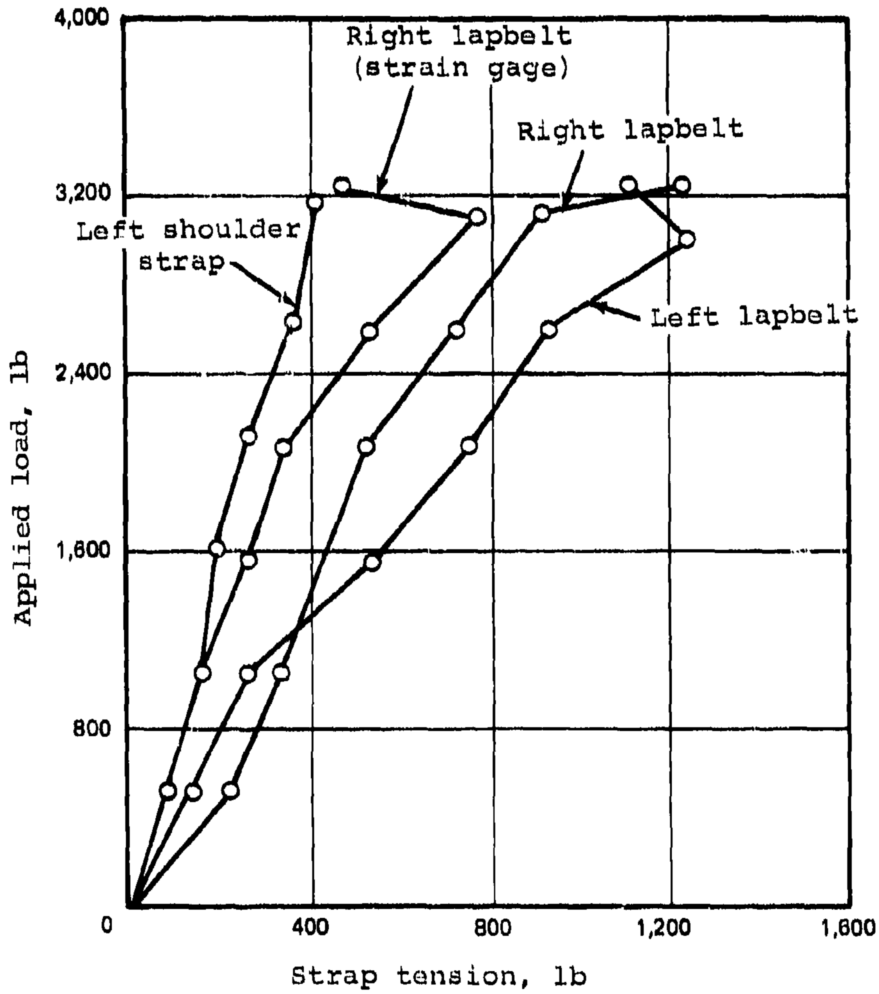

Figure 53. Lapbelt and shoulder strap loads.

designed for the production version of the seat, is the preferred method. However, time and budget did not permit use of this design on the test articles, and a welded joint was employed, using softer weldable tubing. Design modifications for the seats to be dynamic-tested consisted of the addition of 0.125-in.-thick aluminum straps added to the inside and outside of the seat pan corners.

TASK II SUMMARY

Analysis of the static test data shows that the seat functioned properly in the direction of the predominant impact attitudes under forward and combined vertical, forward, and lateral loadings. Difficulty was experienced with the pure lateral load condition, missing the test objectives by a small margin. Replacement of the soft weldable tubing with a higher-strength tubing and the use of a mechanical joint at the corner of the seat pan would provide the adequate strength and rigidity needed to meet the test objectives. Such a design was presented in Reference 5 for a production version of the seat, but a long leadtime was needed and the cost of the corner fitting forging used was too expensive in small quantities for the test articles.

In the aft-facing seat test, some minor intrusion of the force deflection curve into the base area was experienced. However, a minor intrusion into the base area is not as critical for a troop seat as it is for a pilot seat. A pilot is limited in forward stroking, due to the necessity for clearance from the control column and instrument panel. Troop seat installations generally have more forward clearance with hard structure than pilot seats. When this is the case intrusion into the base area is acceptable as long as the energy represented by the area of the intrusion is accounted for by additional stroking. Additional stroking allowances have already been made in the draft Military Specification, Seat, Helicopter, Troop, to allow for the higher flexibility of a troop seat and to permit some intrusion into the base area.

The results of the static test indicate that with the minor modifications of the attenuator load settings, and with redesigned strap anchor fittings installed on the seat, the crashworthy troop seat test articles will function as required in a crash environment. The static test and analysis show that the seats were ready for verification of their crashworthiness functions by dynamic testing.

CRASHWORTHY TROOP SEAT TESTING - TASK III

TASK III REQUIREMENTS

Dynamic testing of a minimum of two aft-facing and two forward-facing seats was required. The required effort under Task III was as follows:

- The fabrication, modification, and assembly of forward- and aft-facing seat systems, in accordance with the approved detail design developed in Task I and the refinements determined to be necessary as a result of Task II static testing.

- The preparation of seat system and test fixtures to perform dynamic testing in accordance with the approved dynamic test plan (Appendix C).

- The performance of dynamic tests on seat systems in accordance with the approved dynamic test plan.

- The analysis of data obtained in dynamic tests for the purpose of verifying the adequacy and feasibility of the design criteria contained in the proposed Military Specification; Seat, Helicopter, Troop, and Chapters 3 and 4 of Reference 9. Those requirements and/or criteria that were insufficient to insure troop seat occupant protection throughout the 95th percentile survivable accident were to be identified, as well as those requirements and/or criteria that exceed the strength or performance criteria necessary to provide troop seat occupant protection during the 95th percentile survivable aircraft accident, or which, because of practical considerations, are proven too stringent to be feasibly met by current technology.

- Criteria and requirements contained in the proposed Military Specification; Seat, Helicopter, Troop, and Reference 9 were to be substantiated, or changes shall be recommended.

Each of these areas is discussed in this report in the order listed above.

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[9] CRASH SURVIVAL DESIGN GUIDE, Dynamic Science; USAAMRDL Technical Report 71-22, Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, October 1971, AD 733358.

FABRICATION AND MODIFICATION OF SEAT SYSTEMS

As a result of static testing, the four remaining seats were modified to eliminate the deficiencies found during Task II. The following modifications were made:

1. Replace the vertical wire-bending attenuators, using larger diameter wire for a higher load setting of 1,450 lb each.

2. Rework the diagonal tubular wire-bending attenuators to reduce the load setting to 1,100 lb each.

3. Reinforce the seat pan front corners.

4. Replace the anchor fittings for attachment of the seat pan support strap to the seat back.

5. Reinforce the hinge fittings for attachment of the diagonal-strut attenuator to the seat pan.

These modifications were accomplished and the seats were readied for dynamic testing. Strain gages were added to the diagonal energy-attenuating cable fork fittings, and to the rod end fittings at the end of the tubular attenuators.

DYNAMIC TEST PREPARATION

Dynamic tests were performed at the FAA Civil Aeromedical Institute (CAMI), Oklahoma City, Oklahoma. A horizontal track was used to simulate both horizontal and vertical crash impacts. The CAMI test track is an impact test device capable of producing a controlled deceleration pulse variable from 0.4 to 60 G's. The device consists of a wheeled test sled which moves along two horizontal rails, an accelerating device, and a sled braking device. The sled is a flat topped vehicle upon which the test specimen is mounted. By use of adapters the test specimen can be mounted in a variety of orientations relative to the impact force vector.

Sled velocity is provided by a Newtonian acceleration system connected through a cable to the sled. This system accelerates the sled at a constant G level to the desired impact velocity over a maximum distance of 68 feet. The sled then coasts freely for 10 feet and is then decelerated by a metal deforming brake system. The deceleration force is produced when the sled contacts wires which pass over the rails and through brake units on either side of the rails. As the wires pass through the brake units, they are plastically deformed by being bent over a series of rollers. This plastic deformation produces a tension force in each wire which is transmitted to the sled. Wire size and the deforming bends

which it undergoes were selected to generate a nominal 2500 lb force to extend each wire. The braking system accommodates a total of 20 wires, providing an impact force capability of 50,000 lb.

The sled deceleration time history is controlled over a wide range of onset rates, G levels, and stopping by selection of the number and location of the decelerating wires in conjunction with control of sled velocity and weight.

Deceleration onset rate can be controlled for 22 feet of braking distance. Total braking distance may be varied from 4 inches to 22 feet, depending on sled velocity and G level. Sled maximum velocity for a 300-lb test specimen is 70 feet per second and for a 2,500-lb test specimen is 45 feet per second.

To simulate vertical impacts, the test fixture was prepared to support the seat with a simulated floor and ceiling. The seat was oriented for impact with 30-degree pitch and 10-degree roll, to provide a force with combined vertical, horizontal, and lateral components (Appendix C). The fixture was then rotated backwards 90 degrees and placed on the horizontally moving sled.

A similar fixture was used for horizontal impacts with a lateral component. The fixture was mounted upright and positioned at a 30-degree yaw angle.

The sled was accelerated, through a series of cables and pulleys, by a lead weight which fell into a container of sand. Elevation of the weight was accomplished by pulling the sled back along the track to a latch mechanism, which was released at the time of the test.

Electronic Instrumentation

The electronic instrumentation system of the CAMI test track is designed for maximum versatility and reliability under the deceleration forces encountered during impact tests. Special provisions have been made for the use of bridge type transducers. This type transducer has proven to be useful and reliable for measuring strain, acceleration, pressure, force loading and low frequency vibrations.

Signals are transmitted from sled-borne transducers to trackside signal conditioners through an umbilical cable attached at one end of the sled and which travels with the sled as it moves down the track. These signal conditions provide excitation to the transducers (3-10 Vdc), amplify the signal, allow low-pass filtering when desired and provide a resistance shunt calibration for each transducer through the entire data

recording system. Filter classes used during the tests are shown in Table 1.

Outputs from the signal conditioners modulate subcarrier oscillators of a high-frequency constant band width multiplexer system. The composite output from the multiplexer system is recorded on wide band magnetic tape. The magnetic tape is reproduced through appropriate discriminators and displayed on an oscillograph recorder for quick look analysis. As required, portions of these data are then reproduced from the magnetic tape-discriminator combination into a high-speed multi-channel analog to digital converter system and placed in a computer compatible form on high density digital tape. Routine reduction of the impact data provides tabular output and scaled plots versus time of acceleration, vector sum acceleration, velocity and displacement for further analysis.

Impact Force Process

The impact process is composed of two basic assembly language routines, one COBOL program and one FORTRAN program. The Force/load process is made up of the same basic and COBOL programs plus a separate FORTRAN program. The processes are run separately, depending on the type of input received, and are capable of handling multiple reels of input. The processes perform the following data handling and computational functions:

1. Converts the binary code from the analog to digital equipment to an IBM code.

2. Calibrates the data based on the mean of the high and low calibration records.

3. Converts the digitizer counts to G's.

4. Selects the starting point on the data tape by finding the two steps in the velocity channel.

5. Digitally filters the selected channels of data.

6. Applies a five point moving average smoothing process to the selected data channels.

7. Computes the vector sum of the X, Y, and Z data channels.

8. Determines maximum values and their time of occurrence.

9. Computes the first integral (velocity) of carriage Z data.

TABLE 1. INSTRUMENTATION				
Test	Data	Type	Range	Filter class
Series 1 Series 2	Chest Pelvis Floor Pan Belts Strains	CEC CEC CEC Entran Lebow Custom	250 G 250 G 250 G 100 G 3500 lb Custom	180 D 180 D 60 D 60 D 4KH_z A 4KH_z A
Series 3	Chest Pelvis Floor Pan Belts Strains	CEC Entran CEC Entran Lebow Custom	100 G 100 G 250 G 100 G 3500 lb Custom	180 A 180 A 60 A 60 A 4KH_z A 4KH_z A

NOTES:

CEC - 4-202-0001

Entran - EGA-160F-100D-SL

Lebow - 3419

Custom - supplied with seat

Filter class is to SAE-J211b analog or ditigal as indicated.

10. Computes the second integral (displacement) of carriage Z data.

11. Builds a graph tape with control information values to produce point plots.

DYNAMIC TESTING

Test Requirements

All tests were to be performed in accordance with the dynamic test plan (Appendix C). The test requirement for a forward-facing seat was a combined downward, forward, and lateral loading, with an impact at 50 fps and a pulse peak of 48 G. In addition, a forward-facing seat was to be tested in a forward direction with a lateral component. Impact velocity was to be 50 fps with a pulse peak of 24 G.

An aft-facing seat was to be tested for combined downward, backward, and lateral loading, with impact at 50 fps and a pulse peak of 48 G. Also, an aft-facing seat was to be tested in a backward direction with a lateral component. Impact velocity was to be 50 fps with a pulse peak of 24 G.

Test 1 - Forward-Facing Seat, Three-Axis Loading

A forward-facing seat was installed in the dynamic test fixture and a 95th percentile dummy with equipment, weighing a total of 243 lb, was strapped into the seat (Figure 54). The seat was oriented to simulate 30-degree pitch down and 10-degree roll. The sled was accelerated horizontally to simulate a vertical drop and impacted the barrier at 49.34 fps.

A visual inspection of the seat after the test revealed no seat structure or fabric failures (Figure 55). Both vertical attenuators had stroked 10.75 in. The right diagonal-strut tubular attenuator was found to have a dent in it resulting from striking a bolt head on the floor. This indicated that the seat had bottomed out on the floor.

The input pulse to the seat was recorded by accelerometers installed on the sled. As the sled impacted the barrier and decelerated, the deceleration level was measured in the direction of impact. Accelerometers on the sled measured the force in G while a timing device measured the sled velocity at the time of impact. The G force was plotted with respect to time (Figure 56). A time base of .063 second and a velocity of 49.34 fps were recorded, both reasonably close to the specified .065 second and 50 fps velocity. A peak G value of 48 G was specified, however, this is a theoretical value. Only the maximum G, which was 45 G, is recorded and plotted, while the

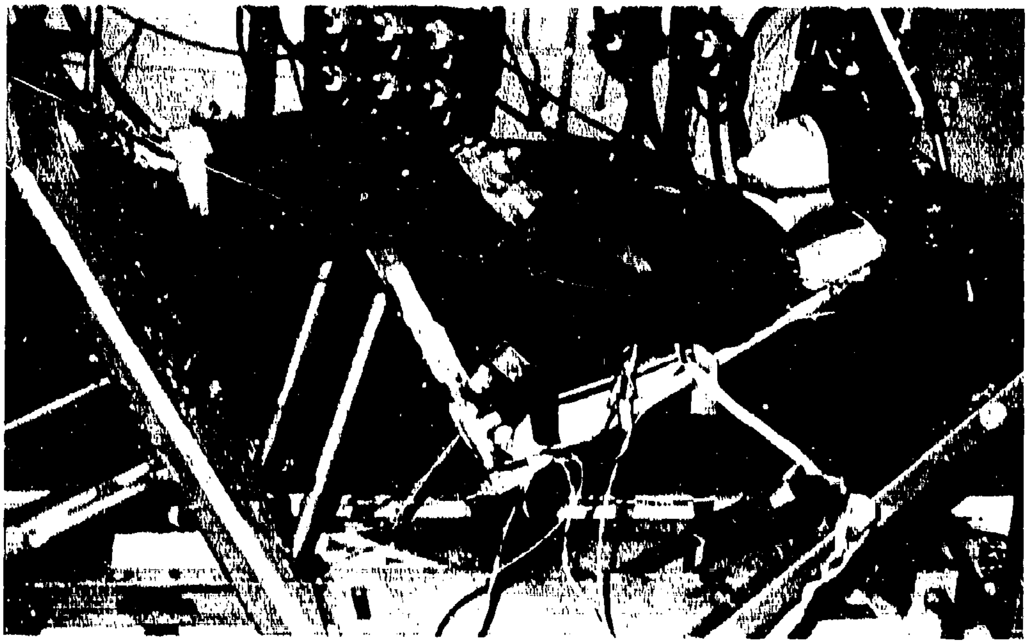


Figure 54. Pre-test 1 - Three-axis loading.

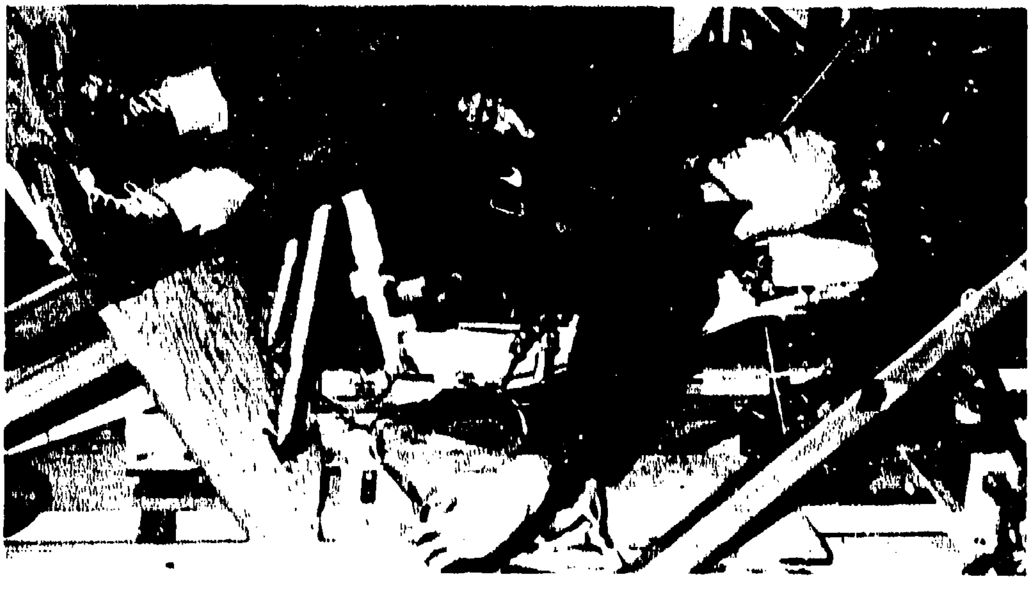


Figure 55. Post-test 1 - Three-axis loading.

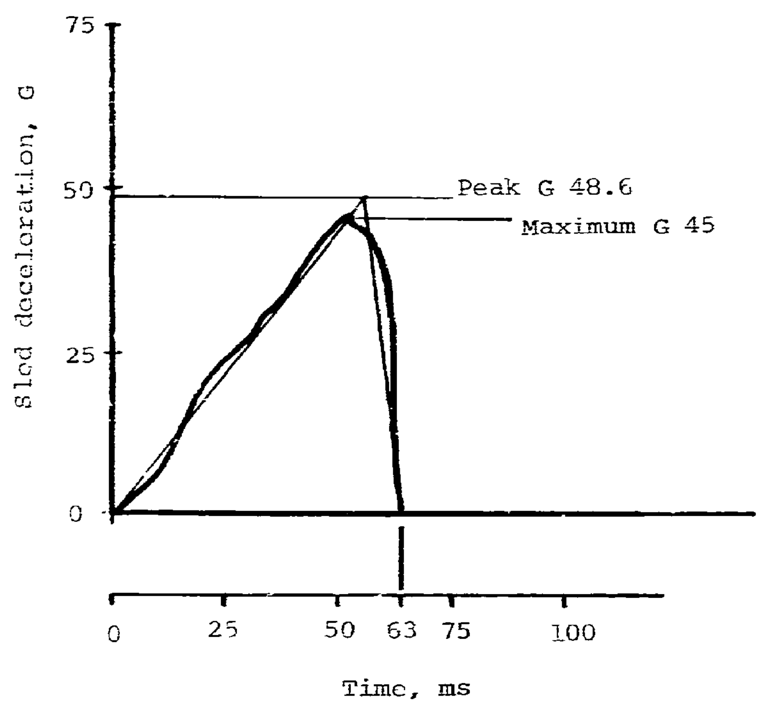


Figure 56. Test 1, sled deceleration time history.

peak G must be calculated. Knowing the velocity and the time base, which are recorded by instrumentation, the theoretical peak G can be determined as follows:

$$32.2\ G_{pk} = \frac{2\ V}{t}$$

$$G_{pk} = 48.64$$

The peak G is superimposed over the recorded pulse data (Figure 56).

Instrumentation data showed that maximum loads and attenuator strokes recorded were as follows:

Instrumented Item	Maximum Load-Lb	Stroke-In.
Right lapbelt	400	-
Left lapbelt	400	-
Right shoulder strap	700	-
Left shoulder strap	400	-
Front diagonal cable	0	0
Rear diagonal cable	0	0
Right diagonal strut	400	0
Left diagonal strut	500	0
Right ceiling attenuator	-	10.8
Left ceiling attenuator	-	10.8

An analysis of instrumentation data verified that there was residual energy in the seat at the time the seat reached maximum stroking distance. Although the seat is theoretically capable of stroking 14.5 in., downward deflection of the front of the seat pan contributed to premature bottoming of the seat. Deflection was a result of seat pan support webbing stretch. However, had the full 14.5-in. stroke been used, there would have been excessive energy left, as shown by the peak of 67 G in the vertical direction registered on the pelvis when the seat bottomed (Figure 57). An initial overshoot condition is shown in Figure 57 with the acceleration on the dummy rising to 21 G. This condition is attributed primarily to two factors. First is the characteristic higher initial force required to start attenuator stroking and secondly is the manner in which the seat was tested. Vertical impact was simulated by laying the seat back and performing the test on a horizontal track. The initial 1 G force of the dummy against the seat pan was not present and additional acceleration of the dummy into the seat pan resulted at impact. The horizontal test (Test 3A which will be discussed later) was conducted in a normal attitude and no overshoot condition was recorded on the pelvis.

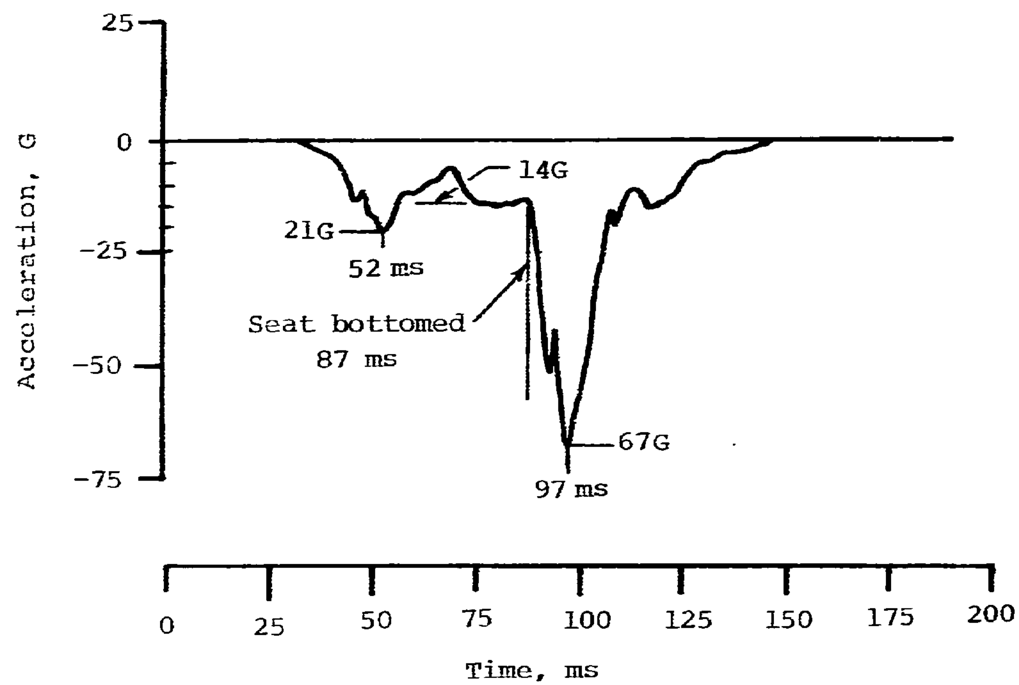


Figure 57. Test 1 - Vertical acceleration, dummy pelvis.

After the initial overshoot condition, the pulse dropped off and stabilized at a plateau of 14 G before the seat bottomed. This plateau was a little high for a 95th percentile equipped occupant. A 14.5 g plateau is the design goal for a 50th percentile equipped occupant having a vertical effective weight of 160.7 lb. Using direct ratio, the G levels can be determined for 95th and 5th percentile clothed and equipped troops with vertical effective weights of 197.2 and 136.7 lb respectively (Table 2). G levels of 12 and 17 G can be expected on 95th and 5th percentile equipped occupants respectively if the attenuating system produces 14.5 G on a 50th percentile equipped occupant. Likewise 22.5 G could be expected on a 5th percentile occupant without equipment. With an average peak acceleration of 12 G on a 95th percentile occupant, a theoretical stroke requirement for the seat-man-sled system can be determined for the required 50 fps impact condition as follows:

$$S = \frac{1}{2}\frac{V^2}{gG} = \frac{50^2}{64.4\text{x}12} = 38.82 \text{ in.}$$

This stroke is at 100-percent efficiency. Efficiency of the sled attenuation system can be determined by comparing the actual and theoretical stroking distances. In this comparison, Table 3 shows an 82-percent efficiency. An efficiency of approximately 80 percent can be expected for the seat, and a required seat stroke for 12 G on a 95th percentile occupant would be 24.25 in. (Table 3).

The seat bottomed out after the sled came to rest, therefore the full sled deceleration distance of 23.5 in. is effective in seat deceleration. Adding the seat stroke of 11 in., a total of 34.5 in. of the required 47.76 in. was attained. A minimum of 13.26 in. additional stroke would be needed to prevent seat bottoming.

The test conclusion reached is that the range of 5th through 95th percentile troops can not be fully protected while meeting the present test requirements and limitations. These requirements and limitations are for impact at 50 fps with an impulse of 48 G, a time base of .065 second, seat stroke limited to that available with a 17 in. seat height and G level limited to 14.5 G on a 50th percentile occupant. One or more of these factors must be changed to permit successful test results. Seat height can not be increased above the 17 in. test seat height, due to the head clearance limitations in UTTAS-type aircraft. This gave a maximum of 14.5 in. stroke on the test seat. G level on the occupant can not be increased without expecting some injury to occur to lighter weight occupants.

TABLE 2. OCCUPANT WEIGHTS			
Item	95th Percentile wt-lb	50th Percentile wt-lb	5th Percentile wt-lb
Troop weight (Reference 10)	201.9	156.3	126.3
Clothing*	7.0	7.0	7.0
Equipment	33.3	33.3	33.3
Total weight	242.2	196.6	166.6
Vertical effective weight clothed	163.9	127.4	103.4
Vertical effective weight equipped	197.2	160.7	136.7

*Includes 4.0 lb for boots

[10] THE BODY SIZE OF SOLDIERS-U.S. ARMY ANTHROPOMETRY-1966, USANL Technical Report 72-51-CE, U.S. Army Natick Laboratories, Natick, Massachusetts, December 1971, AD 743465.

TABLE 3. SEAT STROKE

Test or condition	Item	Velocity change, fps	Peak G	Avg G	Actual stroke (in.)	Calc. stroke (in.) 100% efficiency	Est. or actual efficiency	Required stroke (in.)
Test 1 3-axis fwd-face	System sled seat	50 50 50	-- 48 --	12 24 12	34.5 23.5 11.0	38.82 19.41 19.41	81% (E) 82% (A) 80% (E)	47.76 23.50 24.26
3-Axis	System sled seat	50 50 50	-- 48 --	14.5 24 14.5	-- -- --	32.13 19.40 12.73	80% (E) 80% (E) 80% (E)	40.16 24.25 15.91
3-Axis	System sled seat	50 50 50	-- 34 --	12 17 12	-- -- --	38.80 27.40 11.40	80% (E) 80% (E) 80% (E)	48.50 34.25 14.25
3-Axis	System sled seat	42 42 42	-- 48 --	12 24 12	-- -- --	27.39 13.70 13.69	80% (E) 80% (E) 80% (E)	34.24 17.12 17.12
3-Axis	System sled seat	38 38 38	-- 48 --	12 24 12	-- -- --	22.42 11.21 11.21	80% (E) 80% (E) 80% (E)	28.02 14.01 14.01
Test 2 3-axis aft face	System sled seat	50 50 50	-- 48 --	12 24 12	38.2 23.5 14.7	38.80 19.40 19.40	81% (E) 82% (A) 80% (E)	47.75 23.50 24.25

Note: (A) Actual
(E) Estimate

A reduction of the impulse requirement is the least complex solution. This can be accomplished by reducing the impact velocity or by reducing the impulse to the seat by relying on the aircraft to absorb more of the energy. Newly required energy absorbing landing gear will permit the aircraft to absorb more energy. If the requirement for 50 fps impact velocity is maintained, the peak G to the seat must be reduced from 48 to 34 G. This is necessary while limiting G level on the 95th percentile equipped occupant to 12 G and limiting seat stroke to the available 14.5 in. (Table 3). Reduction of the impact velocity to 38 fps would be required if additional energy could not be absorbed by the aircraft. This is the maximum velocity that can be tolerated if G level on the 95th percentile occupant is limited to 12 G and seat stroke is limited to 14.5 in. (Table 3). A higher impact velocity or a higher peak G could be tolerated, without the seat bottoming, with an equipped 95th percentile troop, or without the non-equipped 5th percentile troop exceeding 23 g, if the 50th percentile occupant acceleration were raised from 14.5 to 16 g.

Test 2 - Aft-Facing Seat, Three-Axis Loading

An aft-facing seat was installed in the test fixture and a 95th percentile dummy without combat pack weighing 220 lb was strapped into the seat face down (Figure 58). The seat was pitched back 30 degrees and rolled 10 degrees. The sled was accelerated horizontally to simulate a vertical drop, and impacted the barrier at 49.44 fps.

A visual inspection of the seat after the test revealed no structure or fabric failures (Figure 59). Both vertical attenuators had stroked 14.87 in. (Figure 60). The diagonal-strut attenuators stroked 0.3 in. in tension (Figure 61). There was no physical evidence of the seat having bottomed out, but the length of the stroked vertical attenuators indicated that bottoming must have occurred.

Instrumentation data showed that the maximum loads and attenuator strokes recorded were as follows:

Instrumented	Maximum load-lb	Stroke-in.
Right lapbelt	400	-
Left lapbelt	400	-
Right shoulder strap	80	-
Left shoulder strap	80	-
Front diagonal cable	-	0
Rear diagonal cable	250	0
Right diagonal strut	1000	.1
Left diagonal strut	1100	.2
Right ceiling attenuator	-	14.9
Left ceiling attenuator	-	14.9

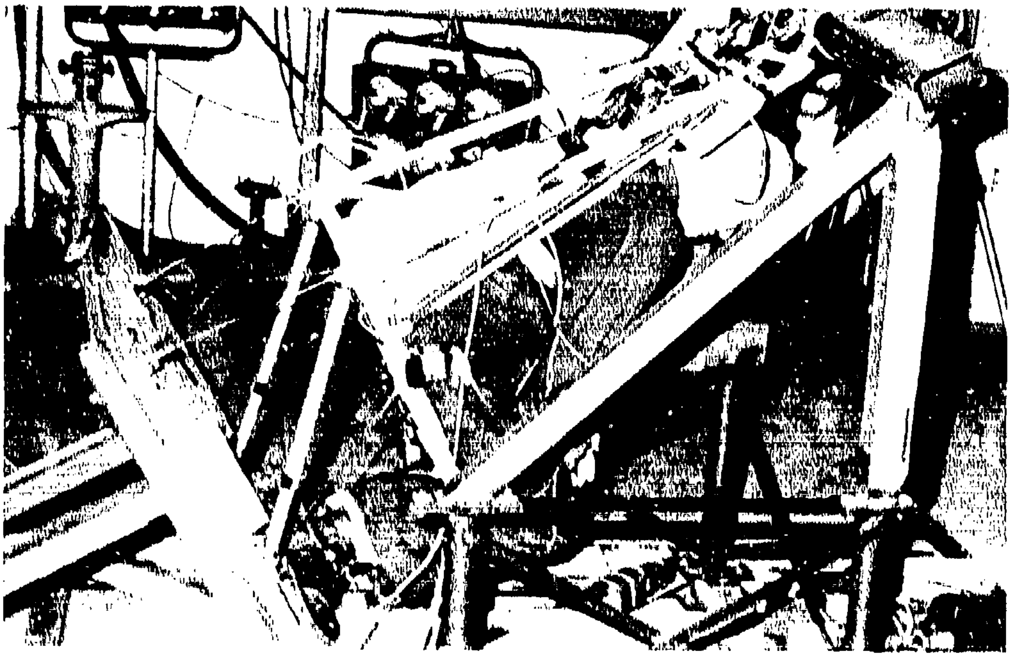


Figure 58. Pre-test 2 - Three-axis loading.

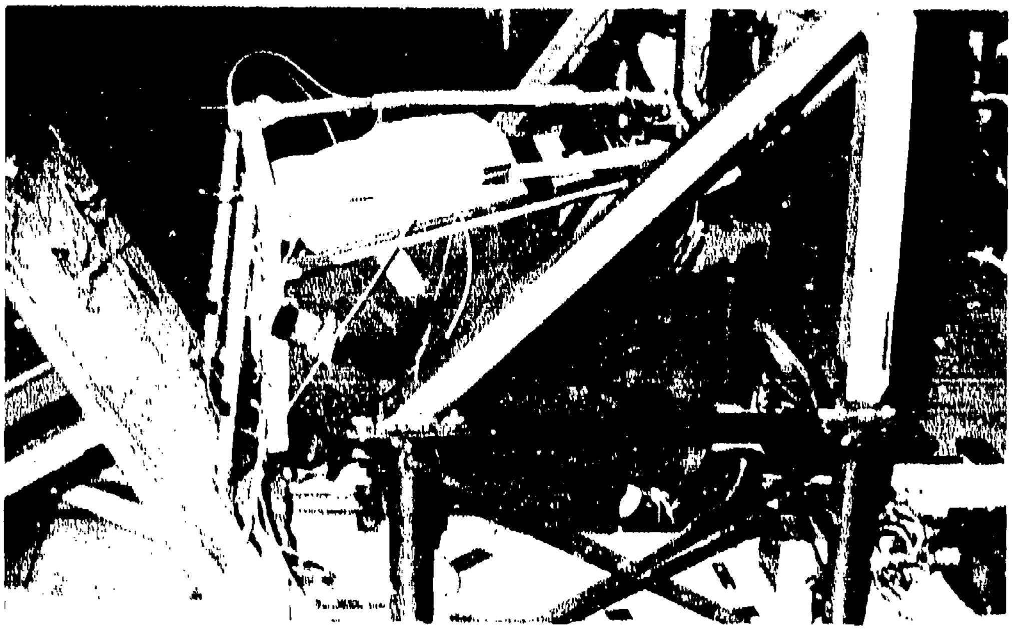


Figure 59. Post-test 2 - Three-axis loading.

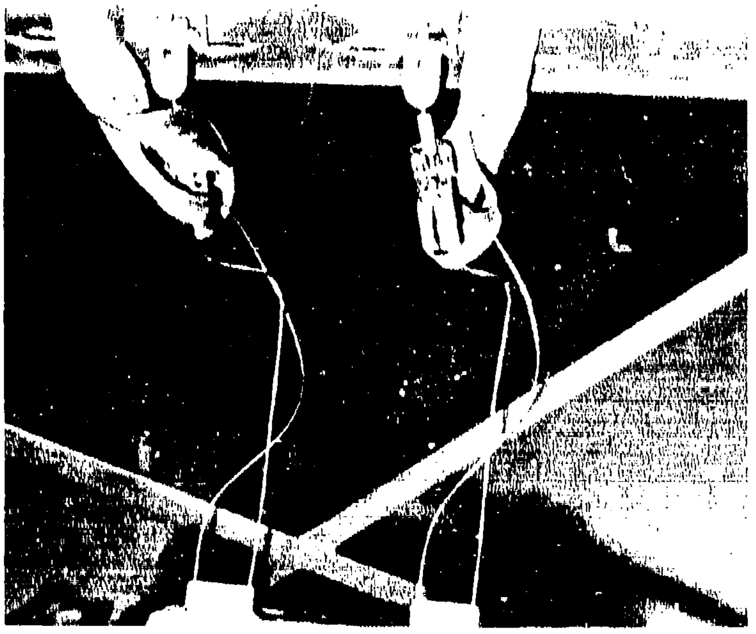


Figure 60. Stroked vertical attenuators.

Figure 61. Stroked diagonal-strut attenuators.

Analysis of instrumentation data showed that the seat bottomed out at 98 milliseconds (Figure 62). An overshoot reaching 78 G occurred. Before bottoming, an initial overshoot occurred which reached 24 G. This overshoot can be attributed to several factors. One is the characteristic higher initial force required to start attenuator stroking. Another is the manner of testing where vertical impact is simulated on a horizontal track by rotating the seat 90 degrees. In this installation the dummy is slung from the seat and does not rest firmly on the seat pan at 1 G. Impact accelerated the dummy into the seat pan contributing to the overshoot condition. Another contributing factor to overshoot was the slippage of the hook and pile tape securing the black flap. This slippage of the hook allowed the dummy to accelerate before bottoming into the combat pack pouch.

Sled velocity recorded at impact was 49.44 fps. Oscillograph data showed a pulse width of .060 second and a maximum of 50 G. Peak G was calculated to be 51.2 G (Figure 63). This was 3.2 G above the 48 G specified.

The sled decelerated over a distance of 23.5 in. The total stroke, including seat stroke, was 38.2 in. A seat stroke of 24.25 in. would be needed to prevent seat bottoming at this impact velocity while maintaining the desired 12 G acceleration for a 95th percentile occupant (Table 3).

Test 1 and Test 2 had similar crash impact requirements and both seats bottomed out during the tests. The test conclusion reached is that the crash impulse was too great for the seat stroke available. The seats are designed for stroking vertically with a 50th percentile occupant during a vertical impact at 42 fps. However, under the combined condition a 95th percentile dummy is used and the impact velocity requirement is increased to 50 fps. This is not compatible with the vertical design requirement.

Test 3 - Forward-Facing Seat, Forward Yaw Loading

A forward-facing seat was installed on the test sled and oriented in a 30-degree yawed position. A 95th percentile dummy with combat equipment was strapped into the seat and weighed a total of 243 lb (Figure 64). The sled was accelerated horizontally and impacted the barrier at 50 fps.

Shortly after impact, the lapbelt buckle failed, releasing the right lapbelt half and causing the dummy to be unrestrained. The shoulder straps remained attached and the full weight of the dummy was taken by the shoulder straps. This excessive load caused the seat back to bend at the point where the strap load was reacted (Figure 65). The dummy remained tied to the seat by the shoulder straps and the left half of the lapbelt; however, the dummy rotated as it left the seat.

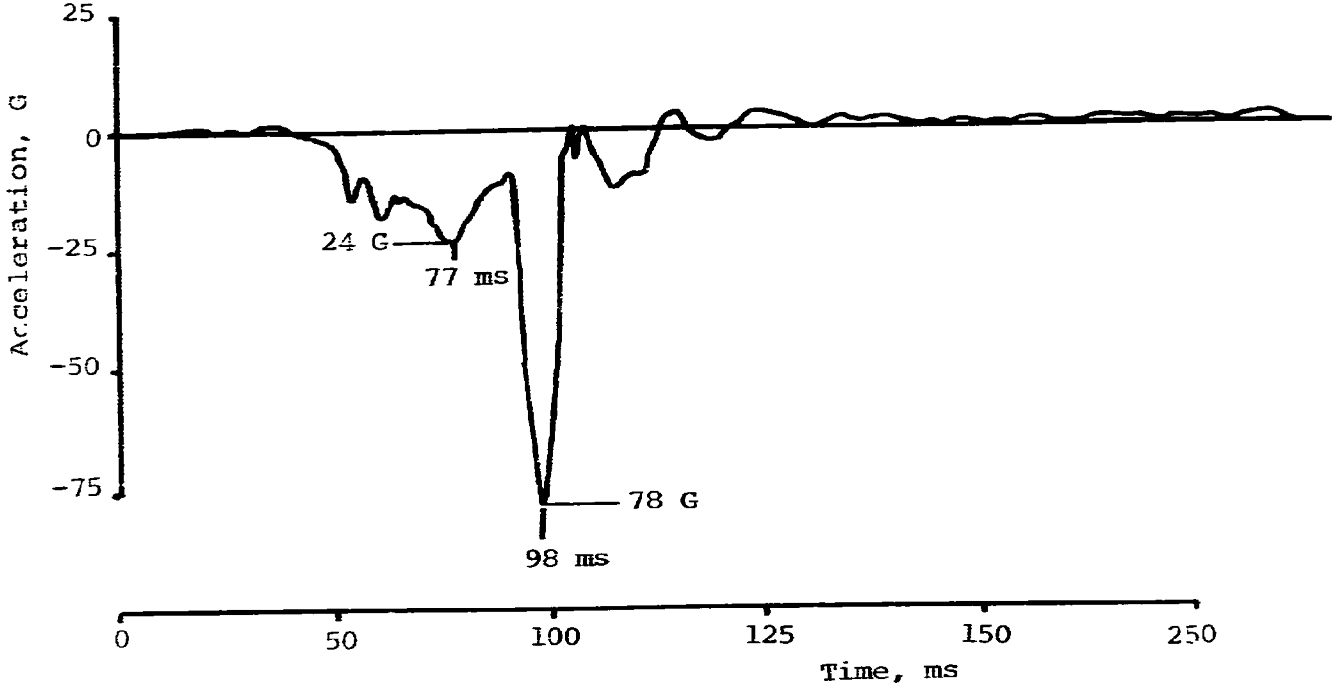


Figure 62. Test 2 - Vertical acceleration, dummy chest.

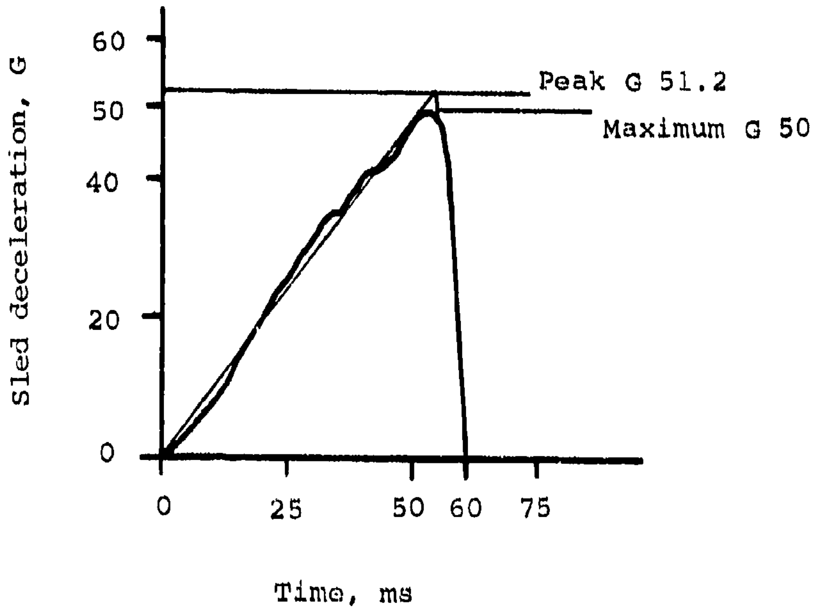


Figure 63. Test 2 - Sled deceleration time history.

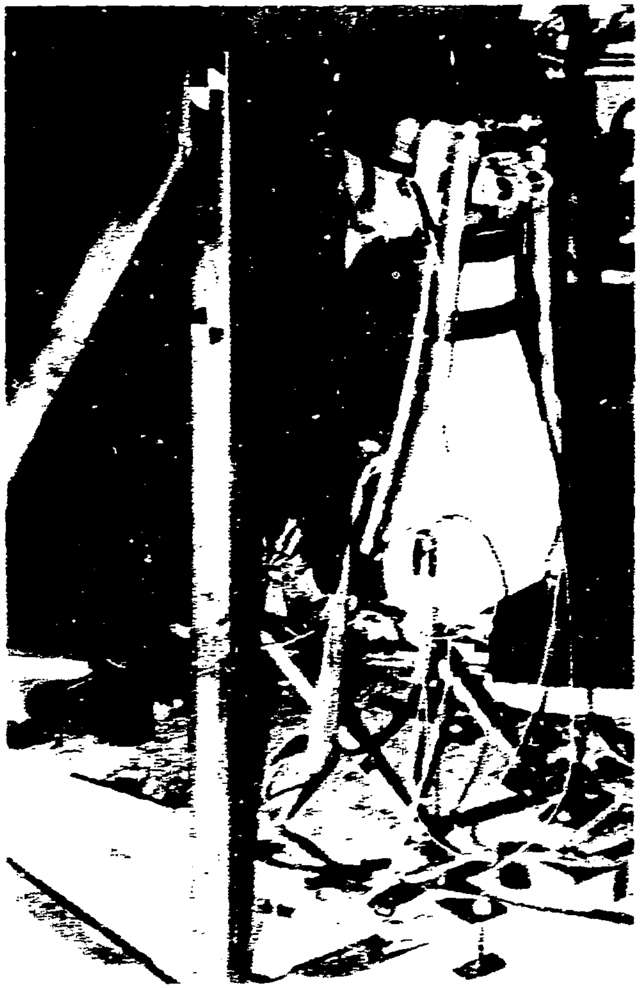


Figure 64. Pre-test 3 - Forward yaw loading.

Figure 65. Post-test 3 - Lapbelt failure.

Instrumentation data showed that the maximum loads and attenuator strokes recorded were as follows:

Instrumented item	Maximum load-lb	Stroke-in.
Right lapbelt	740 (failed)	-
Left lapbelt	2400	-
Right shoulder strap	2000	-
Left Shoulder strap	1100	-
Front diagonal cable	1400	.3
Rear diagonal cable	600	1.8
Right diagonal strut	700	0
Left diagonal strut	1300	.8
Right ceiling attenuator	-	8.9
Left ceiling attenuator	-	6.7

Although the accelerations recorded on the dummy were well within tolerance limits, the data is not reliable due to the rotations which occurred after lapbelt separation.

The conclusion reached after analysis of the test data is that the seat was functioning properly up to the point of lapbelt buckle failure. The attenuators were stroking as required and dummy accelerations were within tolerance.

Test 4 - Rear-Facing Seat, Forward Yaw Loading

A rearward-facing seat was installed on the test sled and oriented in a 30-degree yawed position. A 95th percentile dummy with combat equipment was strapped into the seat; it weighed a total of 243 lb (Figure 66). The sled was accelerated horizontally and impacted the barrier at 50 fps.

After impact, a sequence of failures occurred. The dummy contacted the seat pan support strap attachment, shearing the sheet metal bracket. This allowed the dummy to penetrate the seat back support and contact the tubular back frame. A failure then occurred at the upper right corner of the seat back where the intersecting tubes are welded (Figure 67). Although the seat was extensively damaged, the dummy remained restrained by the seat.

Review of the acceleration data shows that in spite of the seat damage, the dummy received a relatively smooth ride down and accelerations about all axes were within tolerance limits. However, the data was unreliable due to dummy rotation.

Other instrumentation data showed the maximum loads and attenuator strokes to be as follows:

Figure 66. Pre-test 4 - Forward yaw loading.

Figure 67. Post-test 4 - Seat back failure..

Instrumented item	Maximum load-lb	Stroke-in.
Right lapbelt	(Not instrumented)	-
Left lapbelt	(Not instrumented)	-
Right shoulder strap	250	-
Left shoulder strap	3000	-
Front diagonal cable	2000	.9
Rear diagonal cable	-	1.2
Right diagonal strut	1100	4.9
Left diagonal strut	1100	3.9
Right ceiling attenuator	-	4.7
Left ceiling attenuator	-	3.4

FIRST SERIES DYNAMIC TEST SUMMARY

The conclusions reached after performing dynamic Tests 1 through 4 were that some structural modifications of the seats were necessary and a revision to the dynamic test impulse requirements should be made. Improvements to the seat structure were needed to reduce the deflection of the seat pan relative to the seat back. Improvements of the seat back design were required to prevent failure as a result of forward loading on rear-facing seats. An improved lapbelt buckle was also needed.

DYNAMIC TESTING AND ANALYSIS (SECOND SERIES)

Additional dynamic testing was required with modified seats and revised dynamic impulse requirements. The following structural modifications were made to the seats.

1. Replace the welded tubing seat back assembly with higher strength tubing, using mechanical joints.

2. Move the seat pan support point 1 in. further forward on the seat to reduce the moment arm.

3. Replace the seat pan support strap with stronger webbing.

4. Replace the seat pan support attachment sheet metal bracket with a round bar loop fitting.

5. Replace the seat pan welded corner fittings with one-piece formed tubing.

6. Replace the lapbelt buckle with simulated buckle using two aluminum plates bolted together to connect strap ends.

Revisions to the dynamic test requirements were as follows:

1. Change the predominantly vertical three-axis impact velocity requirement from 50 fps to 42 fps, the same as the pure vertical impact velocity requirement.

2. Change the occupant weight requirement for predominantly vertical impact from 95th percentile with full combat equipment to 95th percentile with no equipment, or 50th percentile with full equipment.

3. Forward impact velocity and occupant weight should remain the same.

Six modified and refurbished seats were sent to the FAA (CAMI), Oklahoma City, for the second series of dynamic tests. The four test conditions of the first test series were repeated with slight variations. Velocity for the predominantly vertical three-axis impact condition was reduced from 50 to 42 fps and no equipment was included with the 95th percentile dummy. No changes were made in impact acceleration, velocity, or dummy and equipment weight for the forward impact tests.

The sequence with which the second series of dynamic tests were conducted was not the same as the first series. Discussions on the second series of tests will be presented in the

order that they were performed. However, the test number will be the same for similar tests of both series; a letter suffix designates the repeat of a given test.

Test 1A - Forward-Facing Seat, Three-Axis Loading

A modified forward-facing seat was installed in the dynamic test fixture in a manner similar to dynamic Test 1. A 95th percentile clothed dummy with no equipment and weighing 212 lb was restrained in the seat (Figure 68). The seat was oriented to simulate 30-degree pitch down and 10-degree roll, then was rotated back 90 degree so that a vertical drop could be simulated on the horizontal accelerator sled. A velocity of 41.9 fps was achieved at the time of impact.

A visual inspection of the seat made after the test revealed no structural damage (Figure 69). There was no indication that the seat had bottomed out, and a review of the motion picture film verified this fact. The increased strength of the modified seat pan support strap reduced elongation and eliminated pitch-down of the seat pan, which contributed to bottoming in the previous test. Both vertical attenuators had stroked: the right 9.5 in. and the left 10 in. Since this was a predominantly vertical impact, the diagonal-strut attenuators under the seat were not required to stroke.

Review of the instrumentation data showed that the crash impulse at the floor was a maximum of 40 G and the triangular peak G was calculated to be 44.9 G over a time base of .058 second as a result of a 41.9-fps impact velocity (Figure 70). Accelerometers in the chest and pelvis recorded accelerations about three axies. The more critical acceleration in the vertical axis showed a sine wave curve with an initial overshoot peak of 24 G recorded at the dummy's chest (Figure 71). A second overshoot occurred reaching a peak of 32 G. The first overshoot is attributed to the manner of testing which simulated a vertical impact by using a horizontal track. Initial impact resulted in acceleration of the dummy against the seat pan. The characteristics higher initial force required to start attenuator stroking also contributed to the overshoot. The second overshoot was attributed to slippage of the hook and pile tape, fastening the seat back flap, which allowed the dummy to contact the rear seat pan tube denting it.

Other peak forces recorded were as follows:

Lapbelt	-	780 lb
Right shoulder strap	-	380 lb
Left shoulder strap	-	400 lb
Right diagonal strut	-	430 lb
Left diagonal strut	-	650 lb

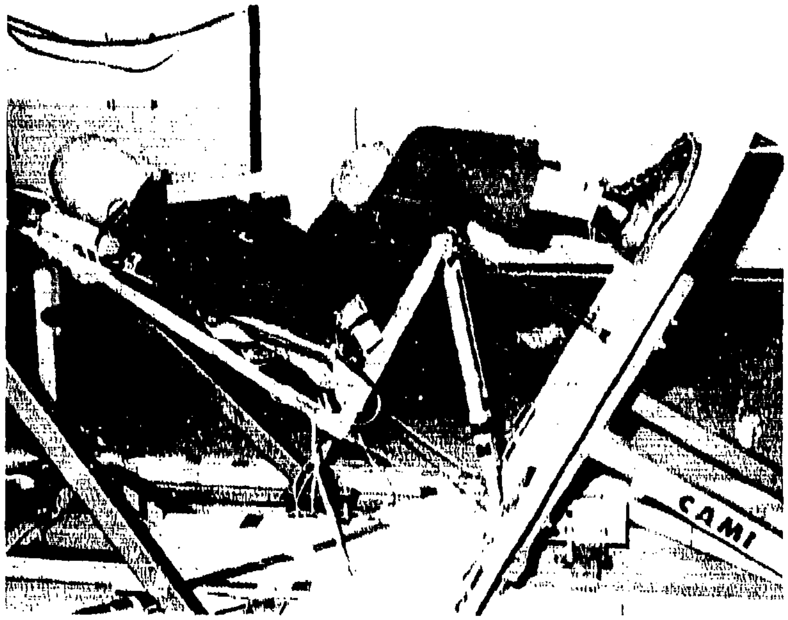


Figure 68. Pre-test 1A - Three-axis loading.

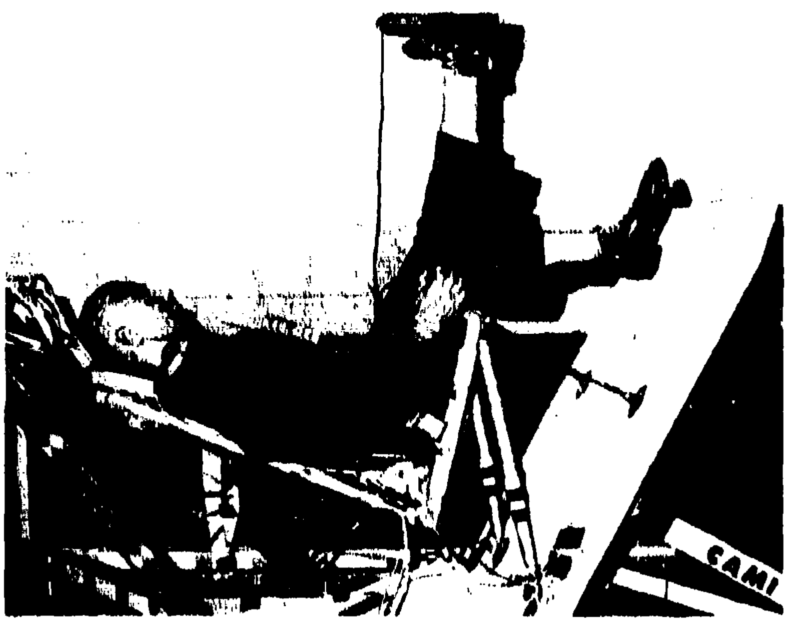


Figure 69. Post-test - Three-axis loading.

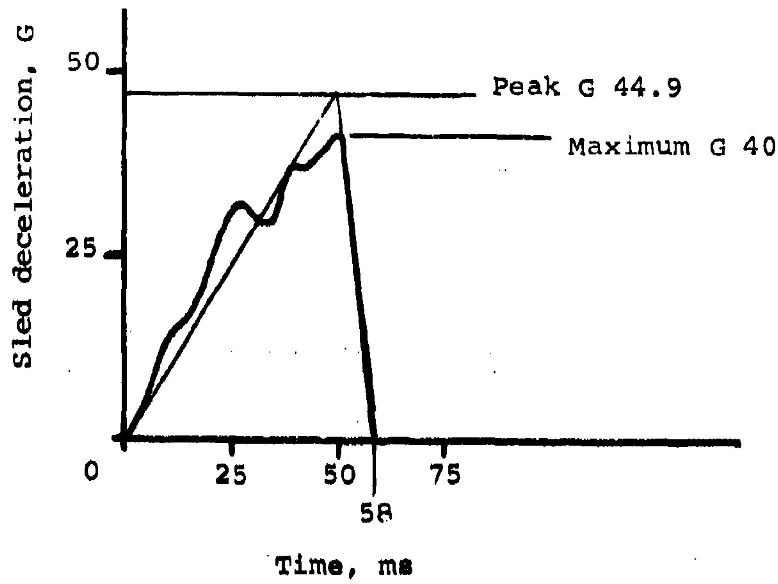


Figure 70. Test 1A - Sled deceleration time history.

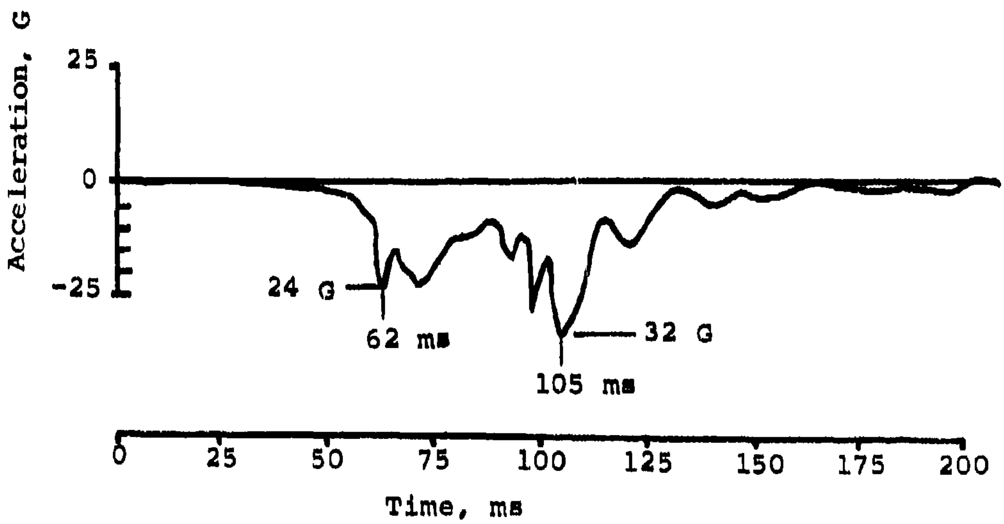


Figure 71. Test 1A - Vertical acceleration, dummy chest.

The test conclusions are that the seat functioned as intended, but overshoot accelerations were excessive. Some refinements could be made, however, to reduce overshoot by attenuator and back flap modifications.

Test 3A - Forward-Facing Seat - Forward Yaw Loading

A modified forward-facing seat was installed on the test sled and oriented in a 30-degree yawed position. A 95th percentile dummy with combat equipment was strapped into the seat; it weighed a total of 243 lb (Figure 72). The sled was acceler-ated horizontally and impacted the barrier at 49.5 fps.

A visual inspection of the seat was made after the test and no structural or fabric damage was detected (Figure 73). A review of the motion picture film showed that the dummy was retained in a proper position throughout the seat stroking sequence. The seat deflected 30 degrees to the left from its original yawed position to align itself in the direction of impact. Swivel fittings at the point of attachment to the floor allowed the seat to realign itself.

All of the attenuators intended to stroke did stroke. The left and right upper attenuators stroked 6.8 and 6.5 in., respec-tively (Figure 74). The left and right diagonal-strut attenu-ators stroked 3.4 and 6.4 in., respectively (Figure 75).

A review of the instrumentation data showed that the crash impulse measured at the floor was a maximum of 19 G with the peak G calculated to be 23.6 G for a time base of .130 second (Figure 76). Plateau peak accelerations measured on the dummy were well within limits. The accelerations in the frontward direction (x axis) were 15 G on the pelvis and approximately 15 G on the chest with a maximum peak of 23 G recorded (Figure 77). The accelerations to the side (y axis) were 7 and 10 G on the pelvis and chest, respectively. Vertical accelerations (z axis) were 12 and 10 G on the pelvis and chest, respectively (Figure 78).

Other peak forces recorded were as follows:

Right lapbelt	-	2450 lb
Left lapbelt	-	1400 lb
Right shoulder strap	-	1300 lb
Left shoulder strap	-	1320 lb
Right diagonal strut	-	830 lb
Left diagonal strut	-	760 lb
Rear diagonal cable	-	400 lb

Figure 72. Pre-test 3A - Forward yaw loading.

Figure 73. Post-test 3A - Forward yaw loading.

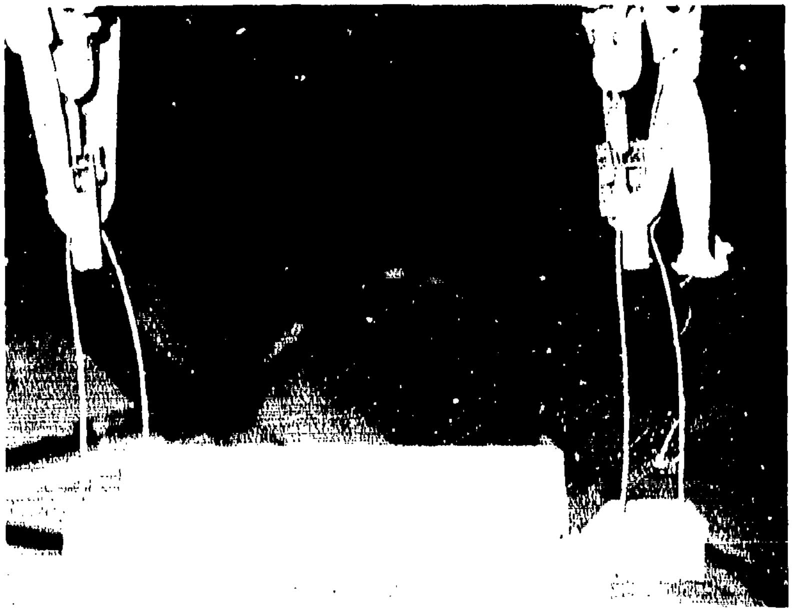


Figure 74. Stroked vertical attenuators.

Figure 75. Stroked diagonal-strut attenuators.

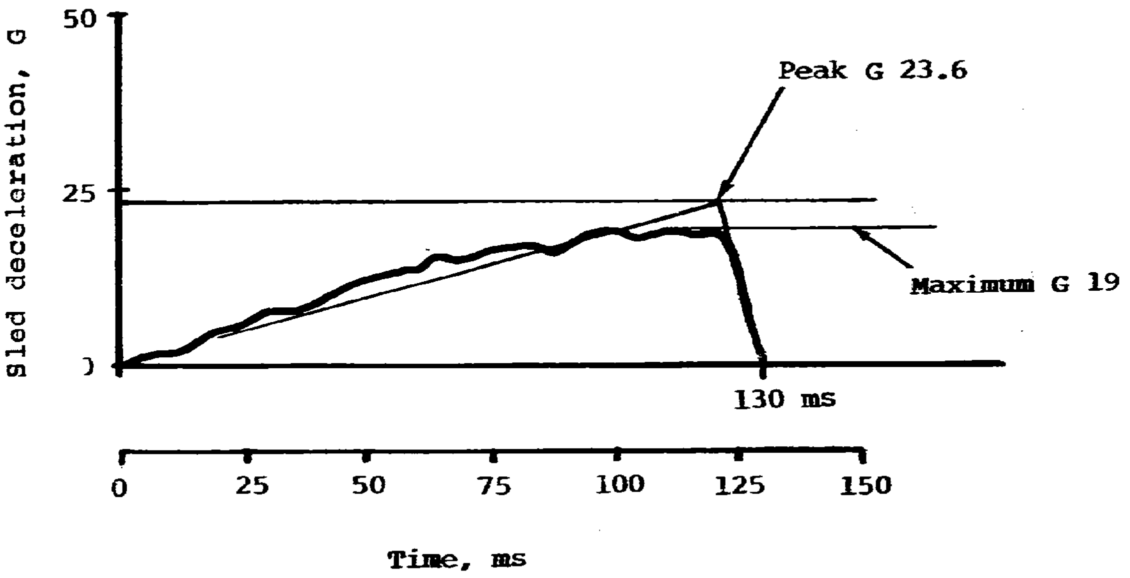


Figure 76. Test 3A - Sled deceleration time history.

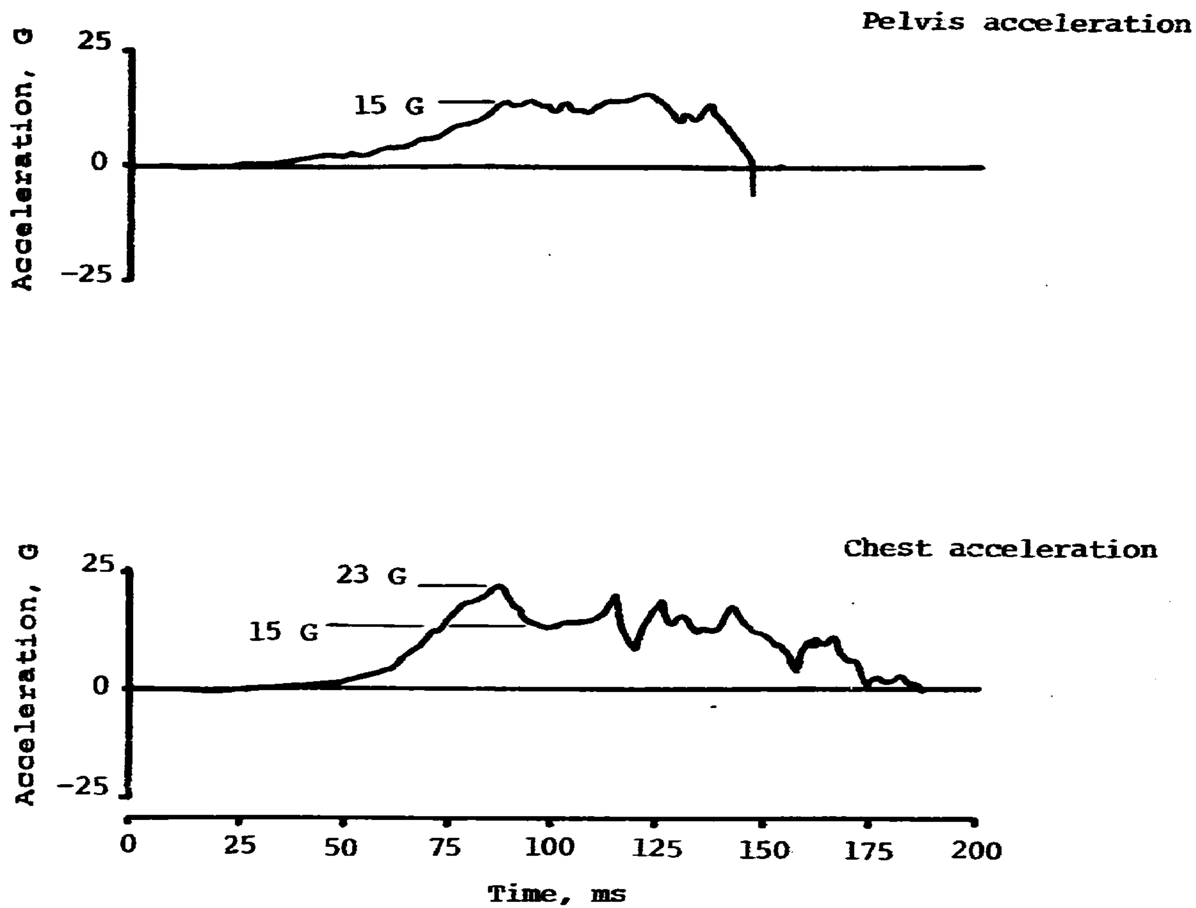


Figure 77. Test 3A - Longitudinal acceleration, dummy pelvis and chest.

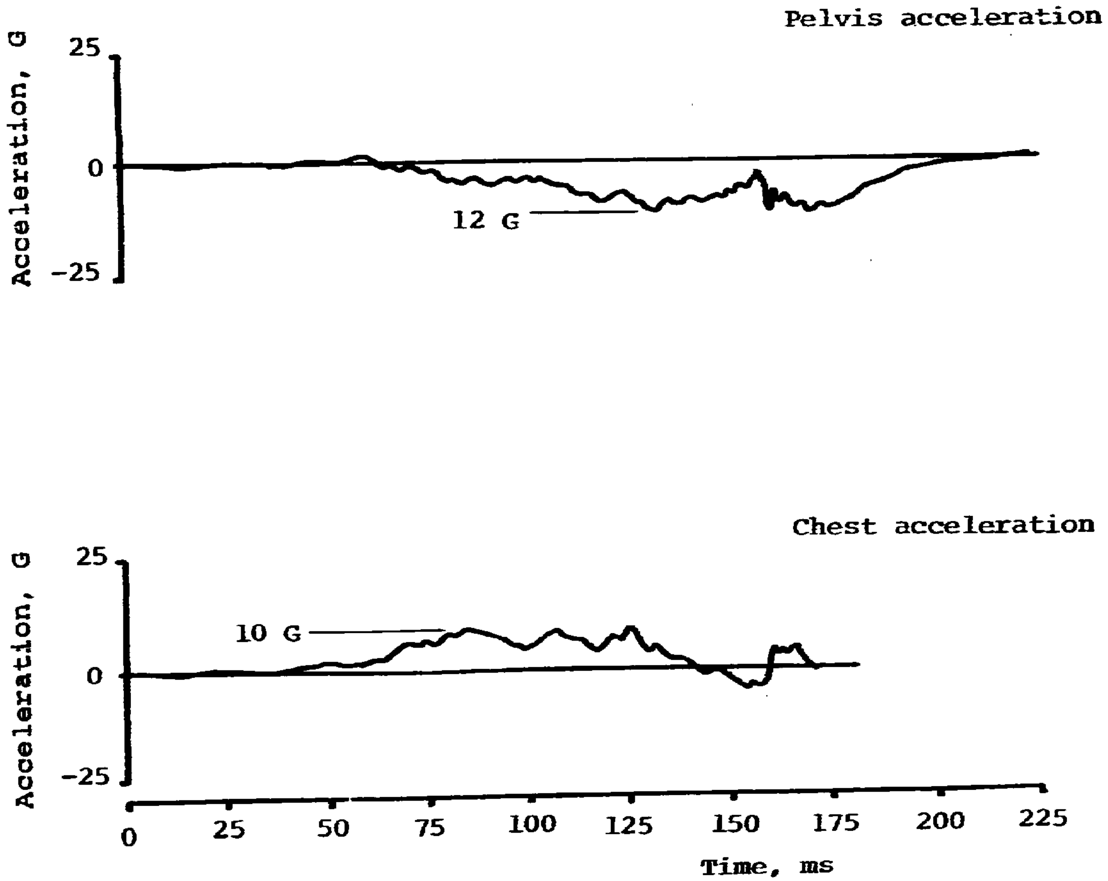


Figure 78. Test 3A - Vertical acceleration, dummy pelvis and chest.

The test conclusions are that the seat system functioned as required. All attenuators required to stroke did stroke and reduced the accelerations on the 95th percentile occupant to well within the desired limits. Extrapolation of the data indicates that a 5th percentile occupant would not exceed the human tolerance limits.

Test 4A - Aft-Facing Seat, Forward Yaw Loading

A modified rearward-facing seat was installed on the test sled and oriented in a 30-degree yaw position. A 95th percentile dummy with combat equipment was strapped into the seat; it weighed a total of 243 lb (Figure 79). The sled was accelerated horizontally and impacted the barrier at 48.5 fps.

A visual inspection of the seat was made after the test and no structural or fabric damage was detected (Figure 80). However, the front diagonal cable anchor pulled out due to the use of a shear nut rather than a tension nut. A review of the motion picture film showed that the dummy was retained in a proper position throughout the seat stroking sequence. The only exception was the right arm flailing and contacting the seat back.

Orientation of the seat changed during the stroke sequence from the 30-degree yawed position to approximately a 45-degree position. This was attributed to the center of gravity of the dummy being off center and behind the seat, which tended to cause some rotation of the seat away from an alignment position. This tendency is a reversal of the forward-facing seat, which tends to align itself. Loss of the diagonal cable also contributed to the additional seat rotation.

All of the attenuators intended to stroke did stroke. The left and right upper attenuators stroked 4.3 and 5.5 in., respectively. The left and right diagonal-strut attenuators stroked 6 in. and 8 in., respectively (Figure 81).

A review of the instrumentation data showed that the crash impulse measured at the floor was a maximum of 27 G. The calculated triangular peak was 26.2 G for a time base of .115 second (Figure 82). Accelerations measured on the dummy were well within limits. Chest accelerations were 21, 10, and 12 G in the x, y, and z axes, respectively (Figure 83). Similar levels were recorded at the pelvis.

Forces recorded on the restraint system were negligible due to the dummy being forced into the seat back. Peak forces of 1000 and 1100 lb were recorded on the left and right diagonal-strut attenuators, respectively.

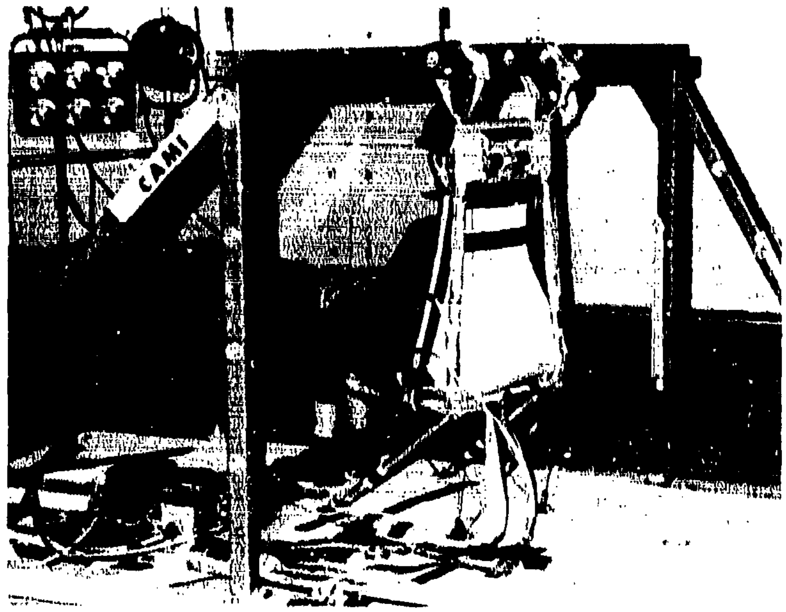


Figure 79. Pre-test 4A - Forward yaw loading.

Figure 80. Post-test 4A - Forward yaw loading.

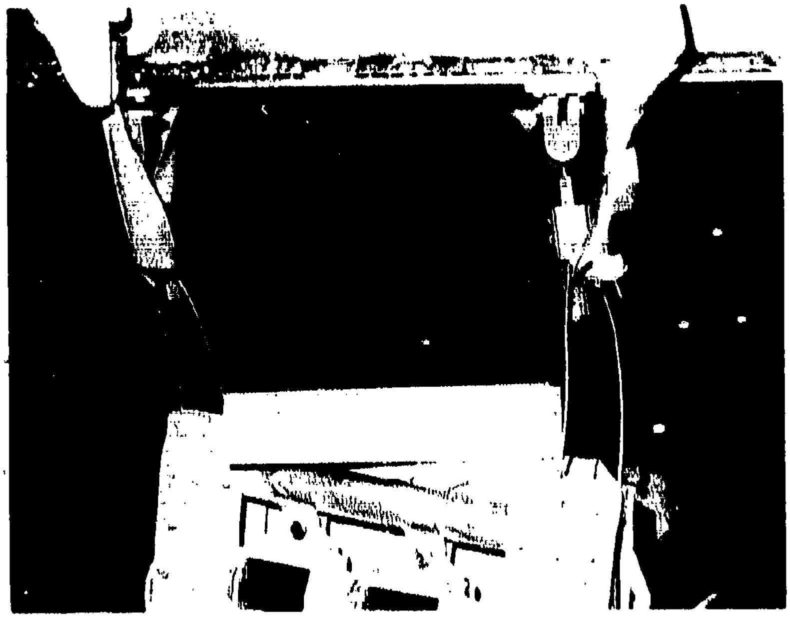


Figure 81. Upper and lower stroked attenuators.

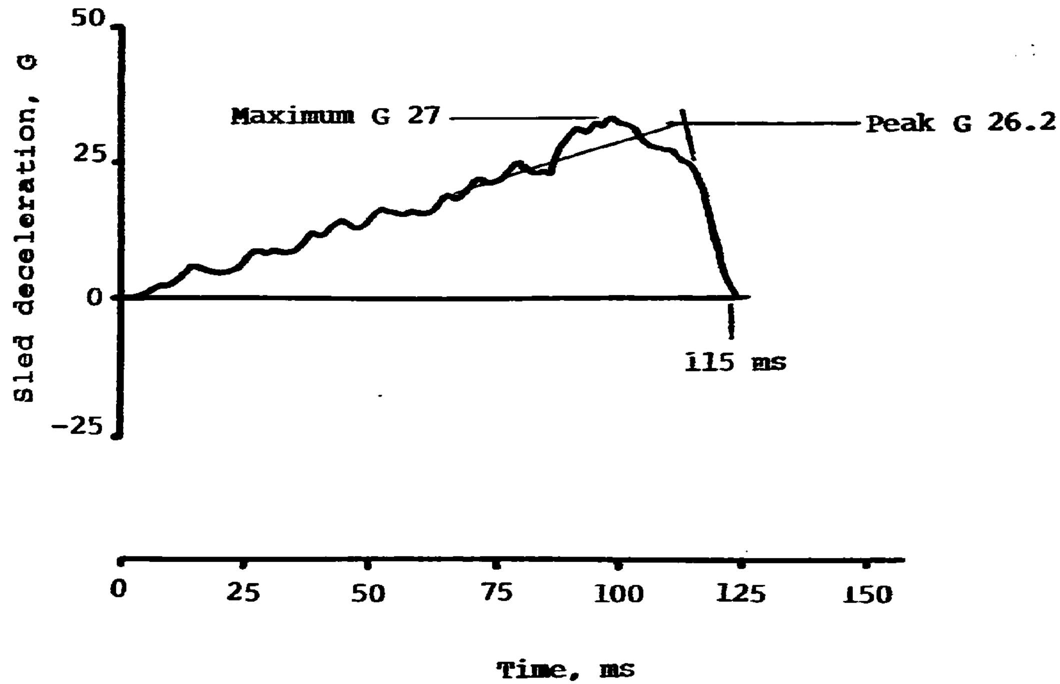


Figure 82. Test 4A - Sled deceleration time history.

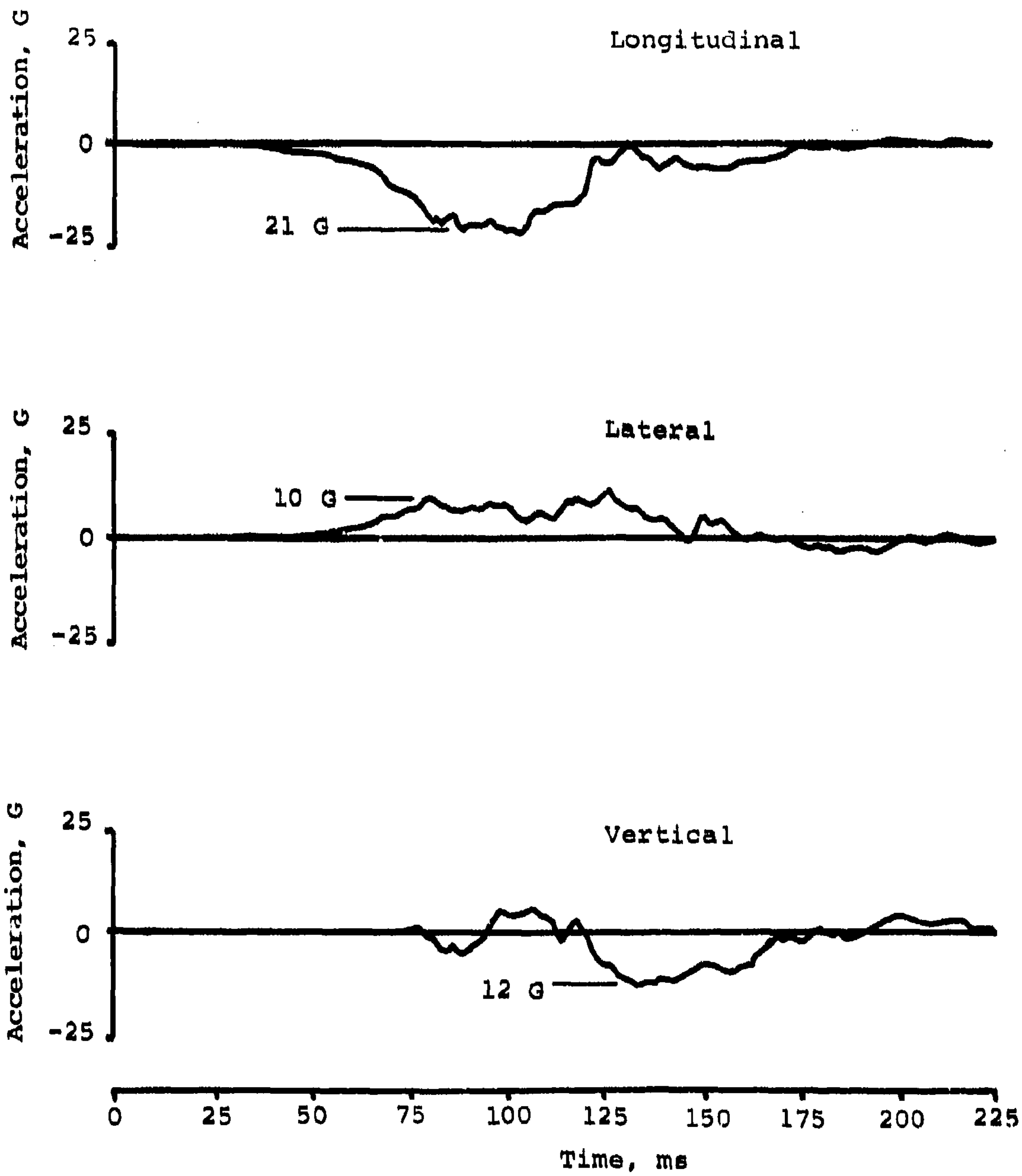


Figure 83. Test 4A - Vertical, longitudinal and lateral acceleration, dummy chest.

The test conclusions are that the seat system functioned as required. All attenuators required to stroke did stroke and reduced the accelerations on the 95th percentile occupant to well within the desired limits. These acceleration levels can be extrapolated to show that accelerations on a 5th percentile occupant would also be within limits. Replacement of the diagonal cable anchor fitting nut will prevent pullout.

Test 2A - Aft-Facing Seat, Three-Axis Loading

A modified aft-facing seat was installed in the test fixture and a 95th percentile dummy without combat pack, weighing 220 lb, was strapped into the seat face down (Figure 84). The seat was pitched back 30 degrees and rolled 10 degrees. The sled was accelerated horizontally to simulate a vertical drop and impacted the barrier at 42.3 fps.

A visual inspection of the seat after the test revealed no structure or fabric damage (Figure 85). Both vertical attenuators had stroked 11 in. (Figure 86). The diagonal-strut attenuators did not stroke; they are not intended to stroke in predominantly vertical impacts. There was no physical evidence of the seat having bottomed, and review of the motion picture film showed that the seat had approximately 2.5 in. of additional stroke remaining before making contact with the floor.

A review of the instrumentation data showed that the crash impulse acceleration was higher than desired, but the time base was shorter. A maximum of 45 G was recorded and the peak G calculated was 52.5 G for a time base of .050 second (Figure 87). Vertical accelerations recorded on the dummy's chest showed an initial overshoot of 25 G which was attributed to the manner of testing and the characteristic higher initial force required for attenuator stroking (Figure 88). The dummy was suspended from the seat face down to simulate vertical acceleration by using a horizontal test track. Looseness of the dummy in the seat caused higher accelerations as the dummy contacted the seat pan at impact. Vertical accelerations at the chest dropped to a plateau of 12 G after the initial overshoot. Longitudinal accelerations on the chest were within limits, with a plateau at approximately 14 G and a maximum peak recorded of 23 G (Figure 88). Accelerations recorded on the pelvis were lower than the chest accelerations.

Forces recorded on the restraint system were negligible due to the rear-facing orientation. Maximum peak forces recorded on the left and right diagonal-strut attenuators were 750 and 1000 lb, respectively.

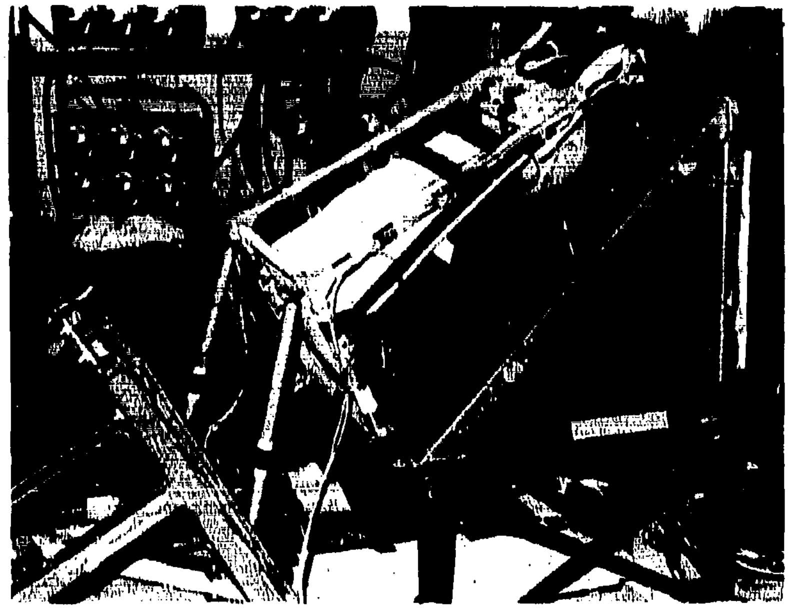


Figure 84. Pre-test 2A - Three-axis loading.

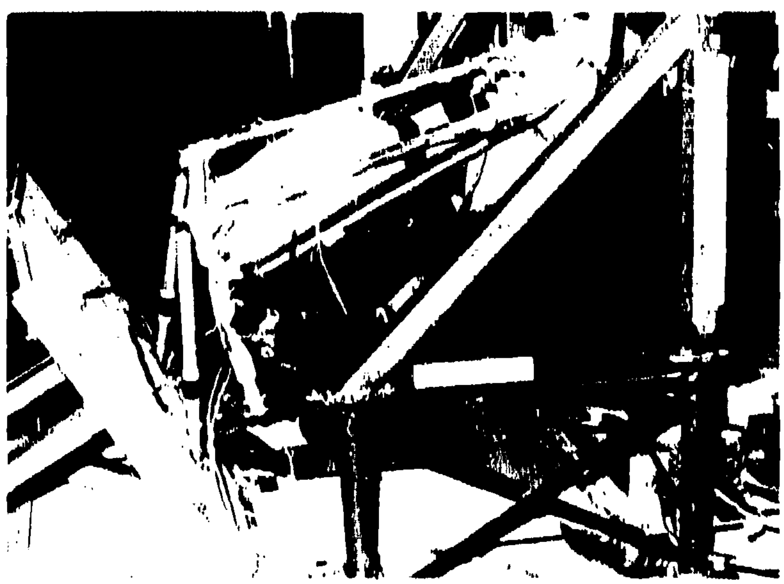


Figure 85. Post-test 2A - Three-axis loading.

Figure 86. Stroked vertical attenuators.

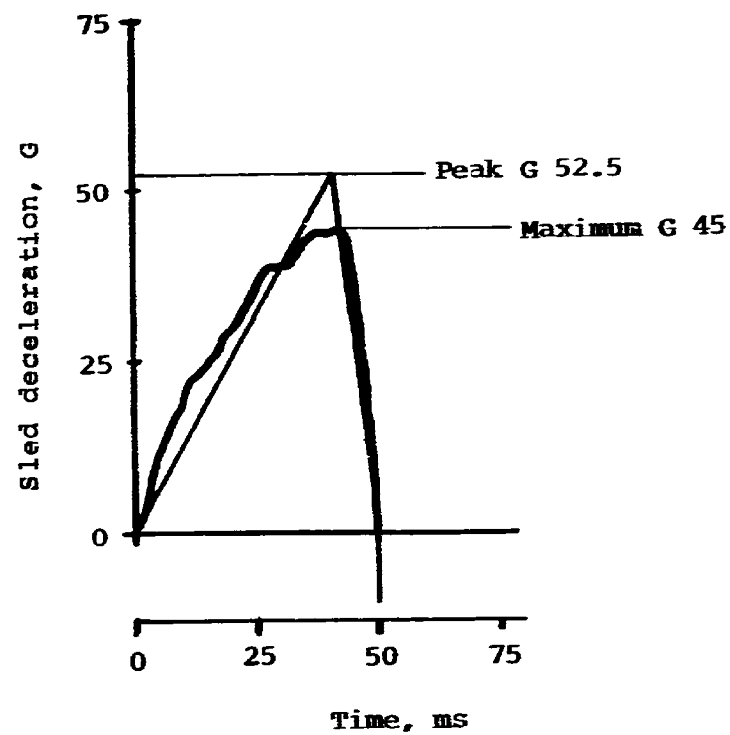


Figure 87. Test 2A - Sled deceleration time history.

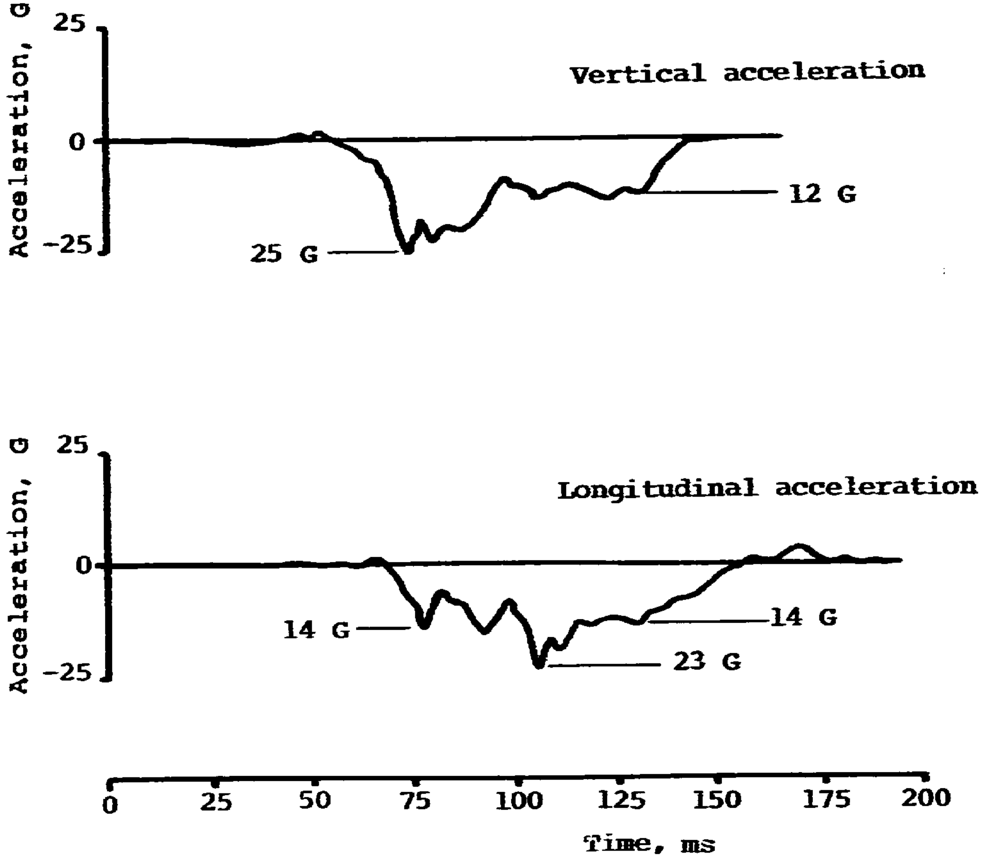


Figure 88. Test 2A - Vertical and longitudinal acceleration, dummy chest.

The test conclusions are that the seat functioned as required. After the initial overshoot, a vertical acceleration plateau level of 12 G was established which is the desired level for a 95th percentile occupant. The initial overshoot of 25 G was excessive but was atributed to the test method and the attenuator characteristic which can be improved.

Test 2B - Aft-Facing Seat, Three-Axis Loading

The same seat used in Test 2A was used for Test 2B. Only the vertical energy-attenuator wires were replaced. A 50th percentile dummy without equipment or clothing and weighing 170 lb was strapped into the seat face down (Figure 89). The relationship of the seat to the impact plane was 30 degrees of pitch back and 10 degrees of roll. The seat was accelerated on the sled horizontally, simulating a vertical drop. Impact velocity was 42.2 fps.

A visual inspection of the seat after the test revealed no structure or fabric damage (Figure 90). The right and left vertical attenuators had stroked 11 and 10.4 in., respectively. There was no physical evidence of the seat having bottomed, and review of the motion picture film showed that the seat had approximately 2.5 in. of additional stroke available before making contact with the floor.

A review of the instrumentation data showed that the maximum impact acceleration recorded was 48 G. The calculated peak acceleration was 52.4 G for a time base of .050 second (Figure 91). Vertical and longitudinal accelerations recorded on the dummy showed two periods of overshoot. Vertical accelerations reached 25 G and 45 G on the chest respectively for the first and second overshoot period. Longitudinal accelerations measured at the chest were 15 G and 33 G respectively for the first and second periods (Figure 92). Acceleration levels recorded at the pelvis were similar to the chest accelerations. The first overshoot condition was attributed to simulating vertical impact on a horizontal track and to the characteristic prestroking peak in the force deflection curve of the vertical energy attenuators. The sharp drop and rise toward the end of the curve is attributed to the dummy penetrating into the combat pack pouch as a result of the pouch cover hook and pile fastener slipping. This penetration allowed dummy contact with the rear seat pan tube which bent the tube. After the overshoot conditions, vertical acceleration stabilized at the desired 14.5 G required for a 50th percentile occupant.

Forces recorded on the restraint system were negligible due to the rear-facing orientation. Maximum peak forces of 750 and 1000 lb were recorded on the left and right diagonal-strut attenuators, respectively.

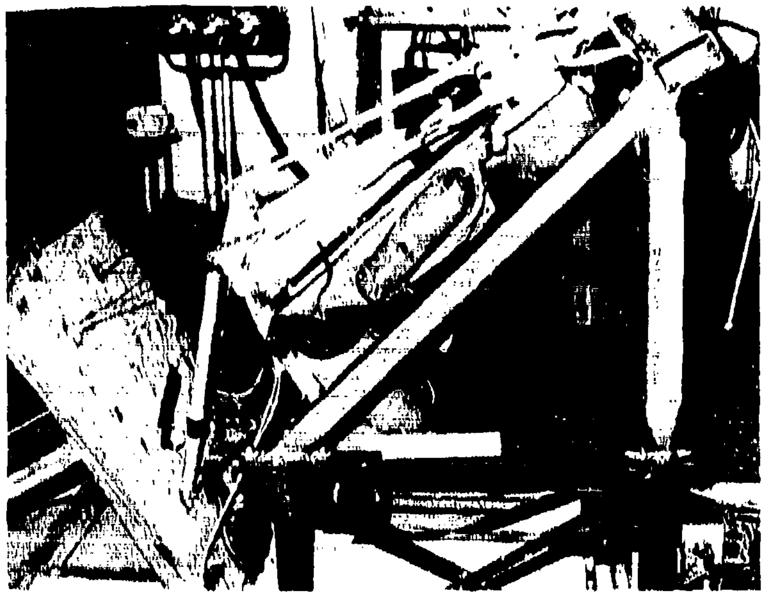


Figure 89. Pre-test 2B - Three-axis loading.

Figure 90. Post-test 2B - Three-axis loading.

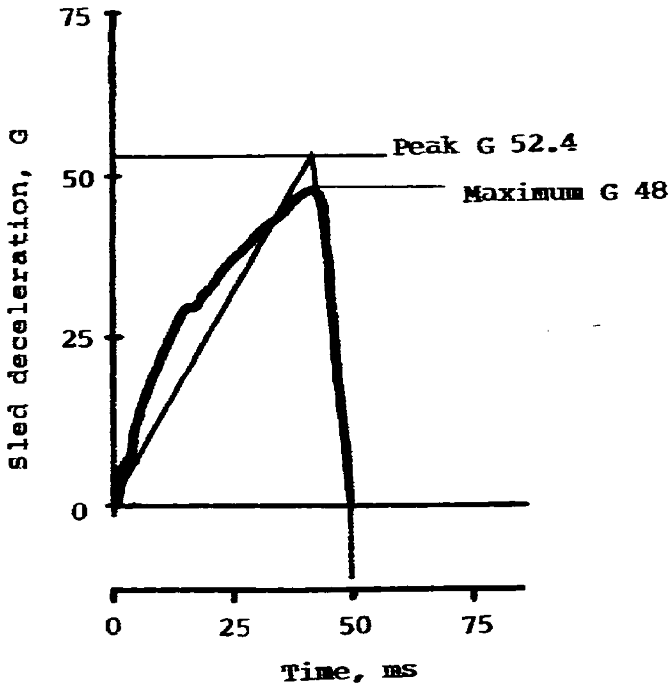


Figure 91. Test 2B – Sled deceleration time history.

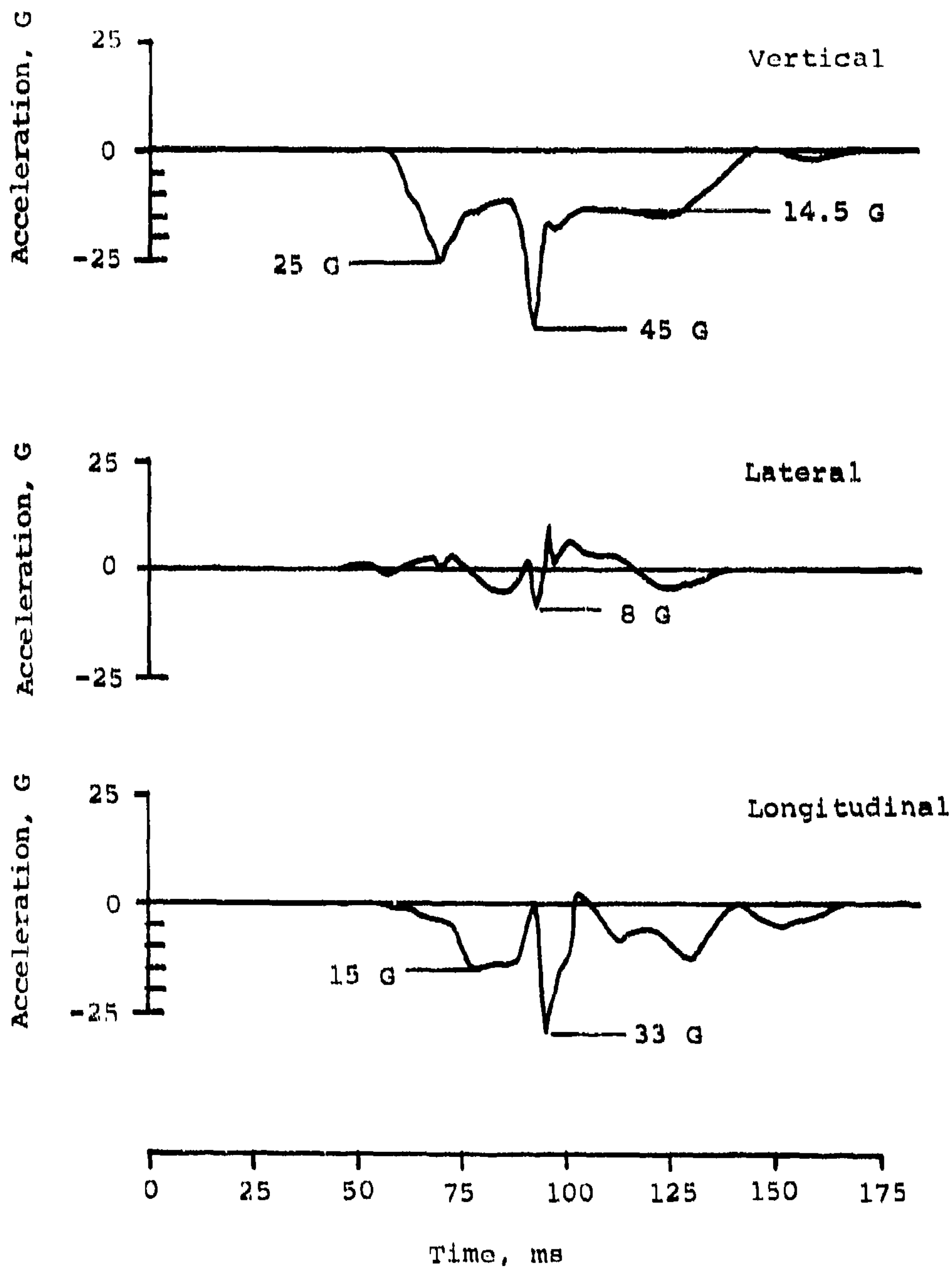


Figure 92. Test 2B - Vertical, longitudinal, and lateral acceleration, dummy chest.

SECOND DYNAMIC TEST SERIES SUMMARY

Conclusions reached after completing the second series of dynamic tests were that all seats functioned properly, all attenuators stroked as required, seat integrity was maintained and the dummy was restrained in the seats in a proper attitude. Some difficulty was experienced with overshoot conditions in the predominantly vertical impact tests. These overshoot conditions were attributed to three factors:

1. The method of testing simulated vertical impact by rotating the seat 90 degrees and accelerating the test specimens on a horizontal track. This procedure required slinging the dummy from the seat back or laying the dummy on the seat back, creating looseness between the dummy and the seat pan. Impact caused additional acceleration of the dummy into the seat pan.

2. The characteristic higher initial force required to start attenuator stroking also attributed to the initial overshoot condition.

3. The seat back flap, used when a combat pack was not worn, was secured with hook and pile tape which slipped under load, allowing dummy penetration into the combat pack pouch. Contact with the rear seat pan tube resulted due to this condition causing a second overshoot spike.

Acceleration level plateaus achieved between and after the overshoot conditions were within the specified levels for the 95th and 50th percentile occupants tested and can be expected to be within the specified tolerances for a 5th percentile occupant. Overshoot conditions can be minimized by improved designs of the attenuators and seat back flap attachments. Use of a vertical drop tower facility would minimize the overshoot condition experienced as a result of simulating vertical drops on a horizontal track.

The assembly drawing for the seat, as modified for these tests, is attached at the end of the report (Page 201). The total weight for the seat system, as modified, using quick-fix methods, was 17.2 lb. Of this weight, the restraint system weighed 2.2 lb. Weight of the seat and restraint system can be reduced below 15 lb by design optimization and material selection.

DYNAMIC TESTING AND ANALYSIS (THIRD SERIES)

Recommendations were made that the two remaining seats not tested be used for a third series of dynamic tests. The principal objective was to reduce the initial acceleration peak recorded on the dummy in the vertical axis. Design modifications were made to the vertical energy-attenuator wire to change from the configuration which had the wire tangent to both rollers, to a configuration which has a slack loop between the first and second roller. This arrangement would permit the attenuator to start stroking at a lower load, thereby eliminating the initial starting peak.

A new attenuator wire configuration was designed with a slack loop before the wire passes over the second roller (Figure 93). Pull tests were conducted on the new configuration and compared with similar tests on the old configuration wire. As anticipated, the initial peak in the force deflection curve, produced by the original wire, was eliminated (Figure 94). Additional tests were run using the old wire configuration to determine the effect of various lubricants on the wire. No change in the force levels were noted as a result of applying various lubricants (Figure 95).

Two seats were modified with the newly-configured upper attenuator wire. These seats were sent to the FAA (CAMI), Oklahoma City, for the third series of dynamic tests.

The test objective was to determine the effect of the new vertical energy attenuator on reducing the initial peak vertical acceleration on the occupant. Vertical, three-axis impact conditions were repeated for a forward-facing and an aft-facing seat. The test impulse objective was a 42-fps impact velocity with an acceleration of 48 G and a time base of .054 seconds. A 50th percentile clothed dummy with full combat equipment was used. The same test number used on similar previous tests will be used for the test discussion; a letter suffix designates the repeats of a given test.

Test 2C - Aft-Facing Seat, Three-Axis Loading

The same seat used in Test 2A and 2B was used for Test 2C; only the vertical energy-attenuator wires were replaced. A 50th percentile dummy with equipment and clothing and weighing 204 lb. was strapped into the seat face down (Figure 96). The relationship of the seat to the impact plane was 30 degrees of pitch and 10 degrees of roll. The seat was accelerated on the sled horizontally, simulating a vertical drop. The impact velocity was 49.04 fps, 7 fps above the desired velocity of 42 fps.

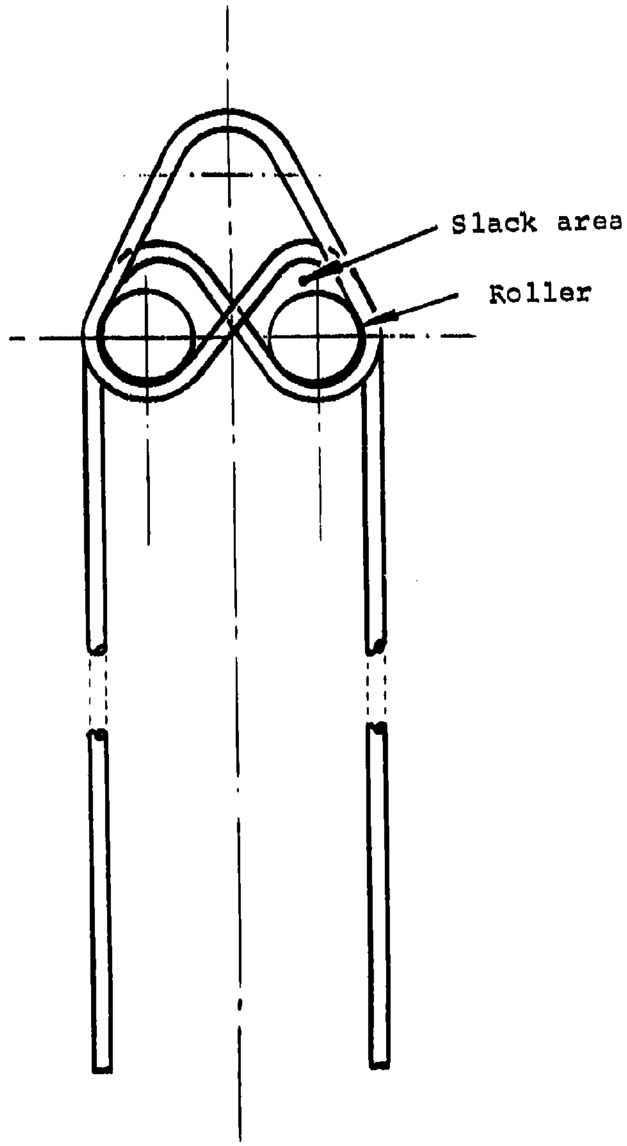


Figure 93. Slack-loop energy-attenuator wire.

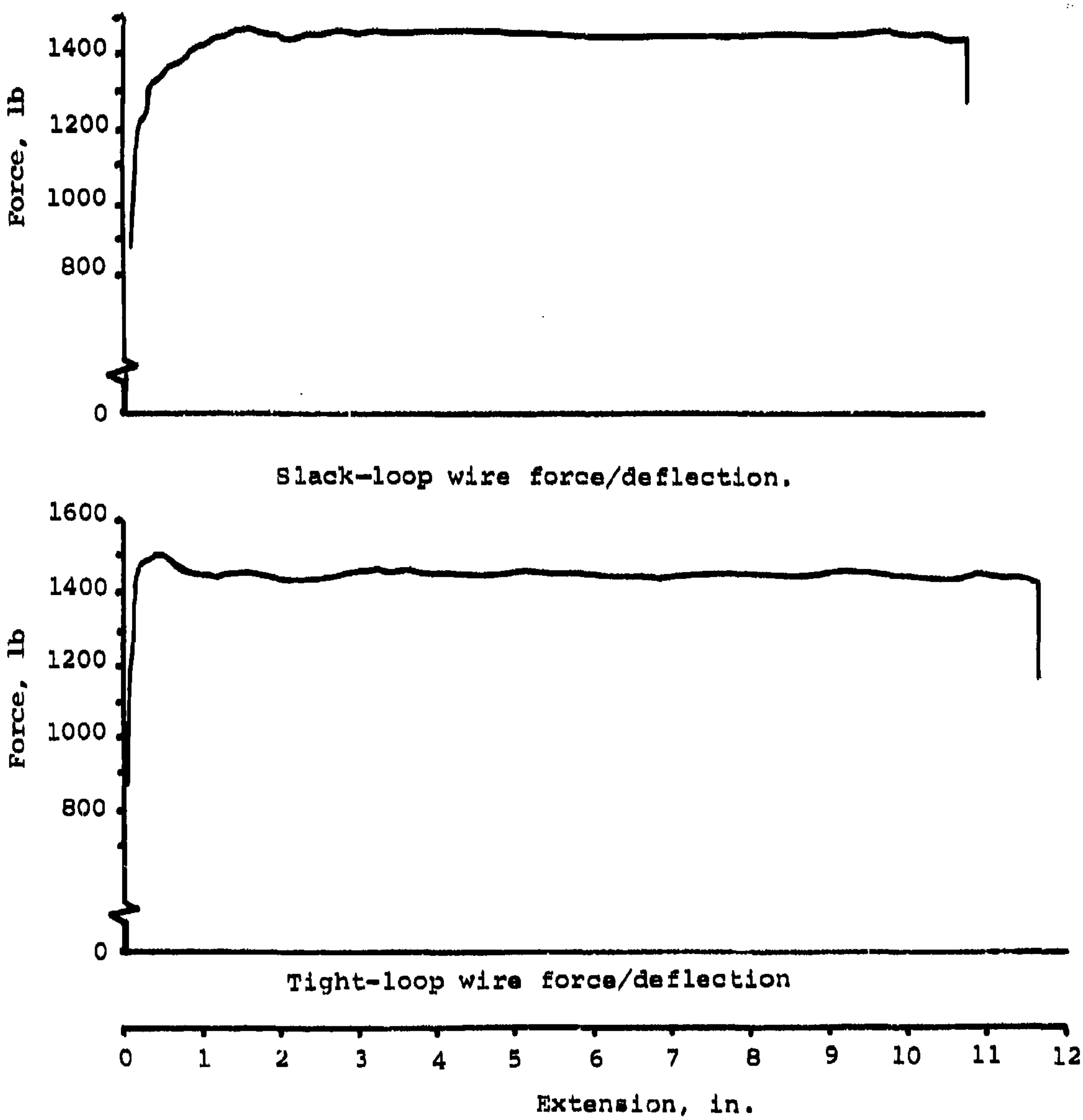


Figure 94. Force/deflection comparison, tight and slack loop.

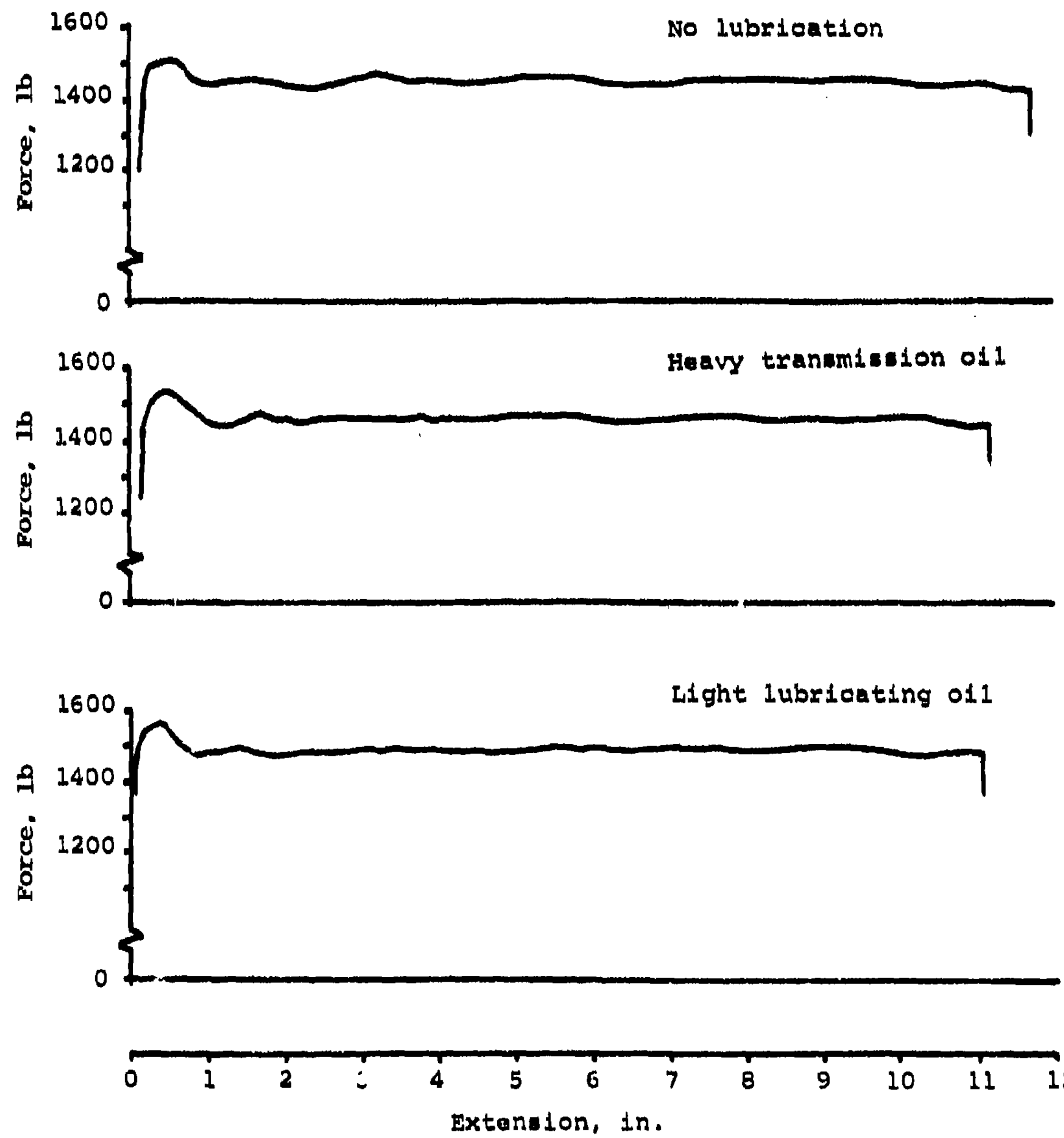


Figure 95. Effect of wire lubrication on attenuator stroking forces.

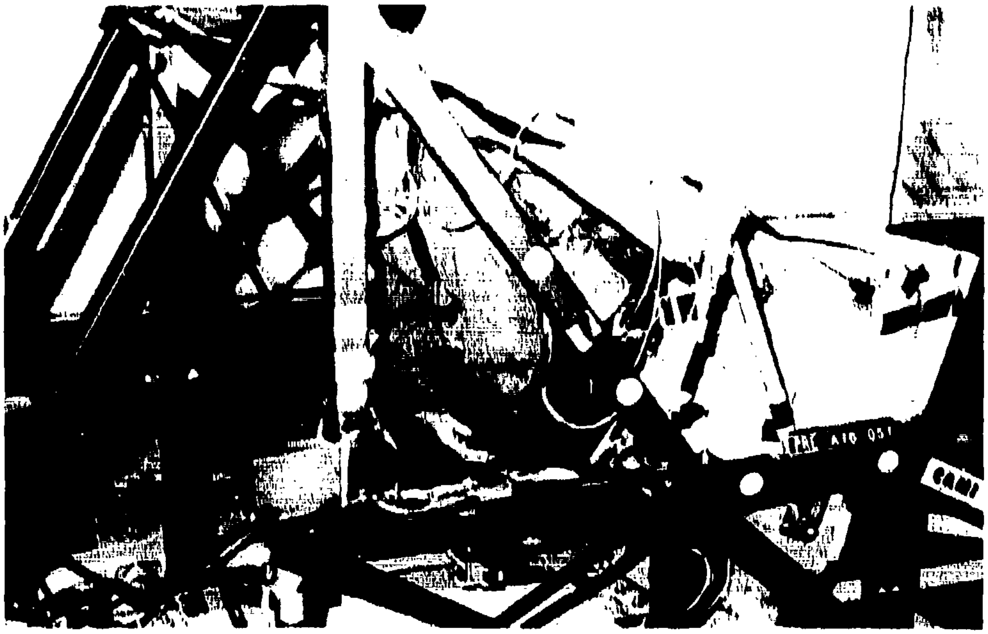


Figure 96. Pre-test 2C - Three-axis loading.

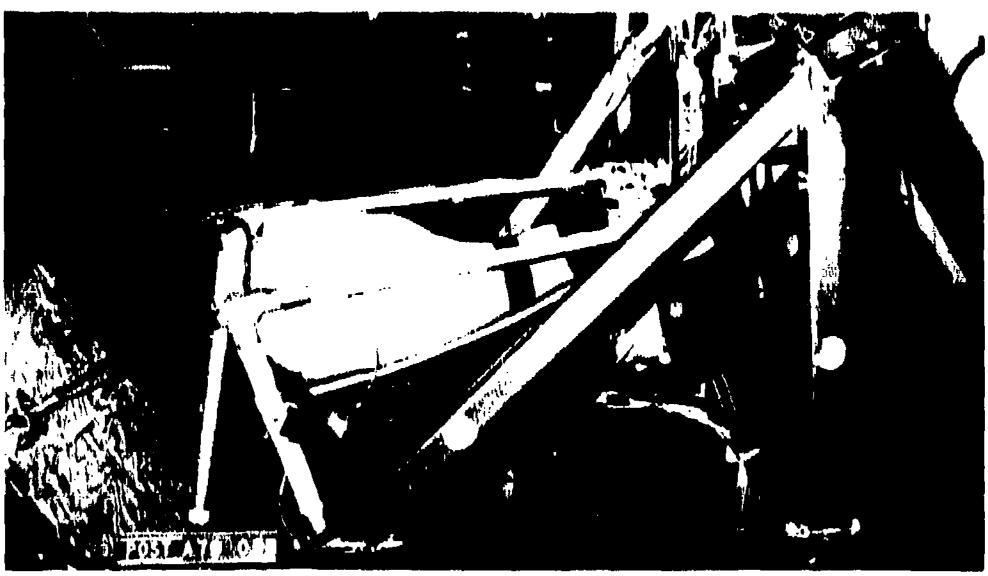


Figure 97. Post-test 2C - Three-axis loading.

A visual inspection of the seat made after the test revealed no structure or fabric damage (Figure 97). A slight deformation of the rear seat pan tube was noted and was attributed to the combat pack, loaded with lead bars wrapped in cloth, accelerating downward and striking the tube. The right and left vertical attenuators had stroked 11.7 and 12.1 in. respectively. There was no physical evidence of the seat having bottomed, and review of the motion picture film showed that the seat had approximately 1.5 in. of additional stroke available before making contact with the floor.

A review of the instrumentation data showed that the impact acceleration was higher than desired. This resulted in the seat stroking a greater distance than anticipated.

The maximum impact acceleration recorded on the sled was 46.4 G. The calculated peak acceleration was 60.9 G for the time base of .050 second (Figure 98). Vertical acceleration levels recorded on the dummy's chest and pelvis showed two overshoot periods (Figures 99 and 100). However, the first overshoot period was modified by the effect of the new configuration attenuator. A peak of 19 G was recorded on the chest, then leveled off before reaching a peak of 25 G. This peak is attributed to the acceleration of the dummy against the seat pan due to the method of simulating vertical drop on a horizontal track. The second overshoot condition was attributed to the combat equipment (lead plates in the ammunition pouches and a lead-packed combat pack) bottoming on the dummy and seat pan. Accelerations in the x axis (rearward) produced minor peaks and valleys about the average peak acceleration and can be attributed to the elasticity of the fabric seat back as the dummy bottomed against the back. However, the maximum peak of 25 G recorded was well within human tolerance limits (Figure 99).

Forces recorded on the restraint system were negligible due to the rear-facing orientation. Diagonal-strut forces both peaked at 1000 lb, the left strut stroking 0.6 in. and the right strut 0.1 in.

Test conclusions are that the objectives for the new vertical attenuator were met. The new attenuator configuration reduced the initial acceleration peak on the dummy in the vertical direction when compared with Figures 88 and 92. The seat functioned as required, stroking, maintaining its integrity and restraining the dummy in proper attitude. Attenuation acceptability was inconclusive due to the two overshoot periods.

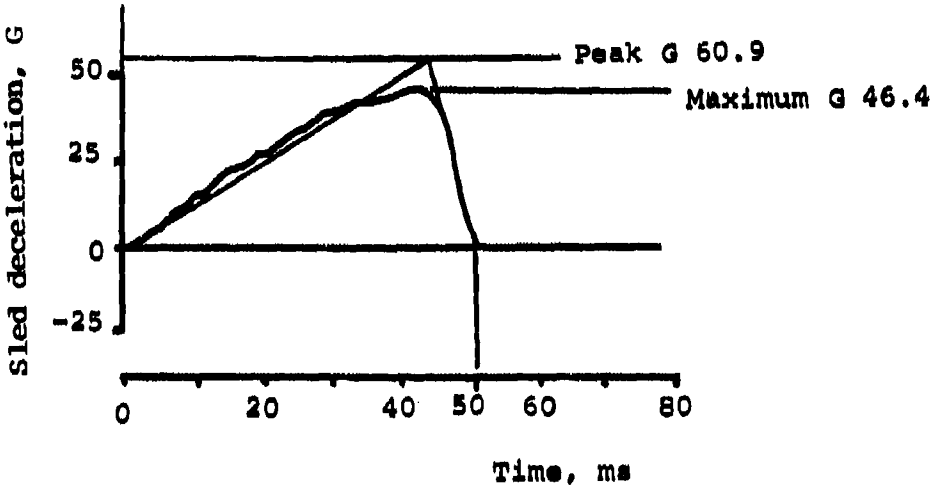


Figure 98. Test 2C - Sled deceleration time history.

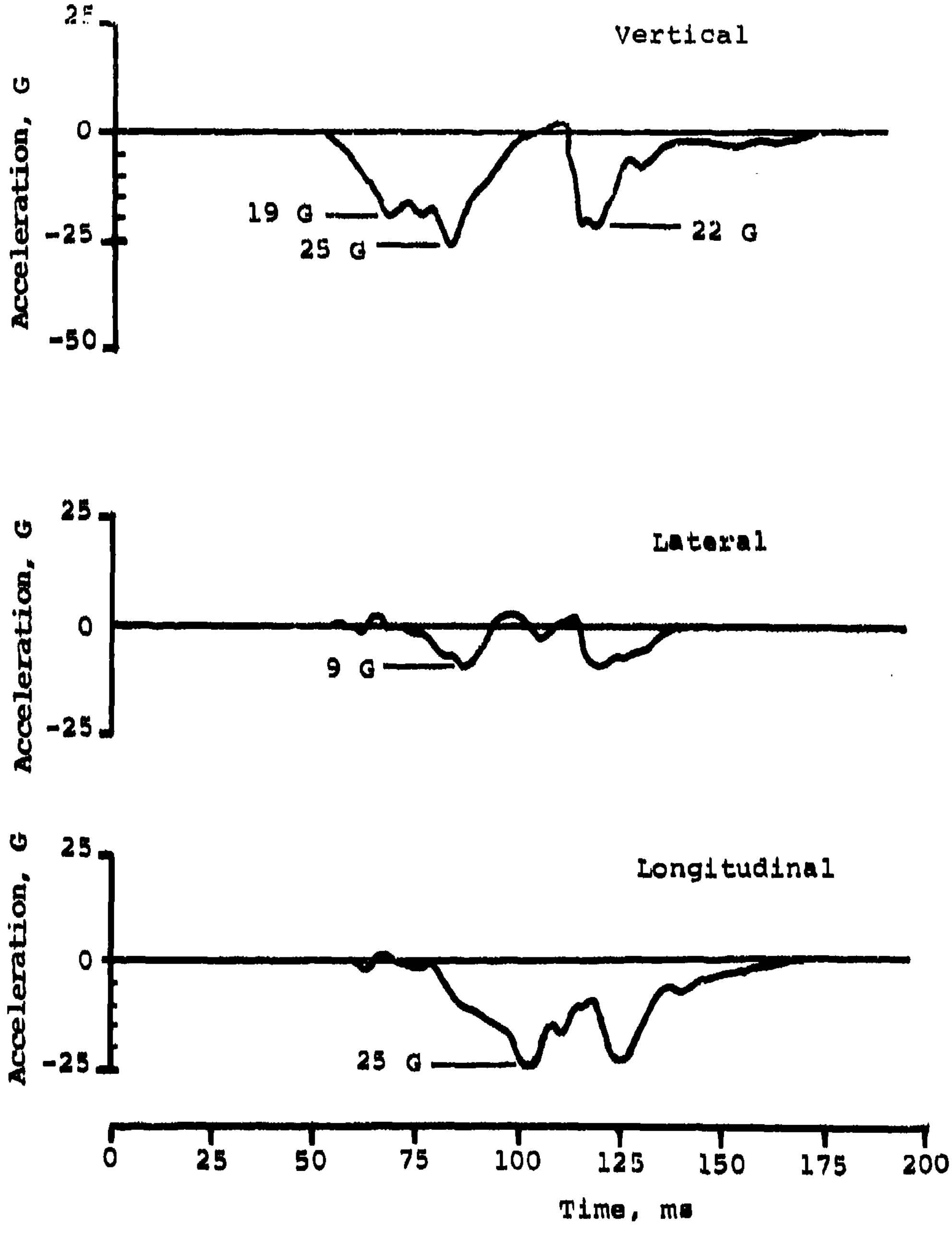


Figure 99. Test 2C - Vertical, longitudinal, and lateral acceleration, dummy chest.

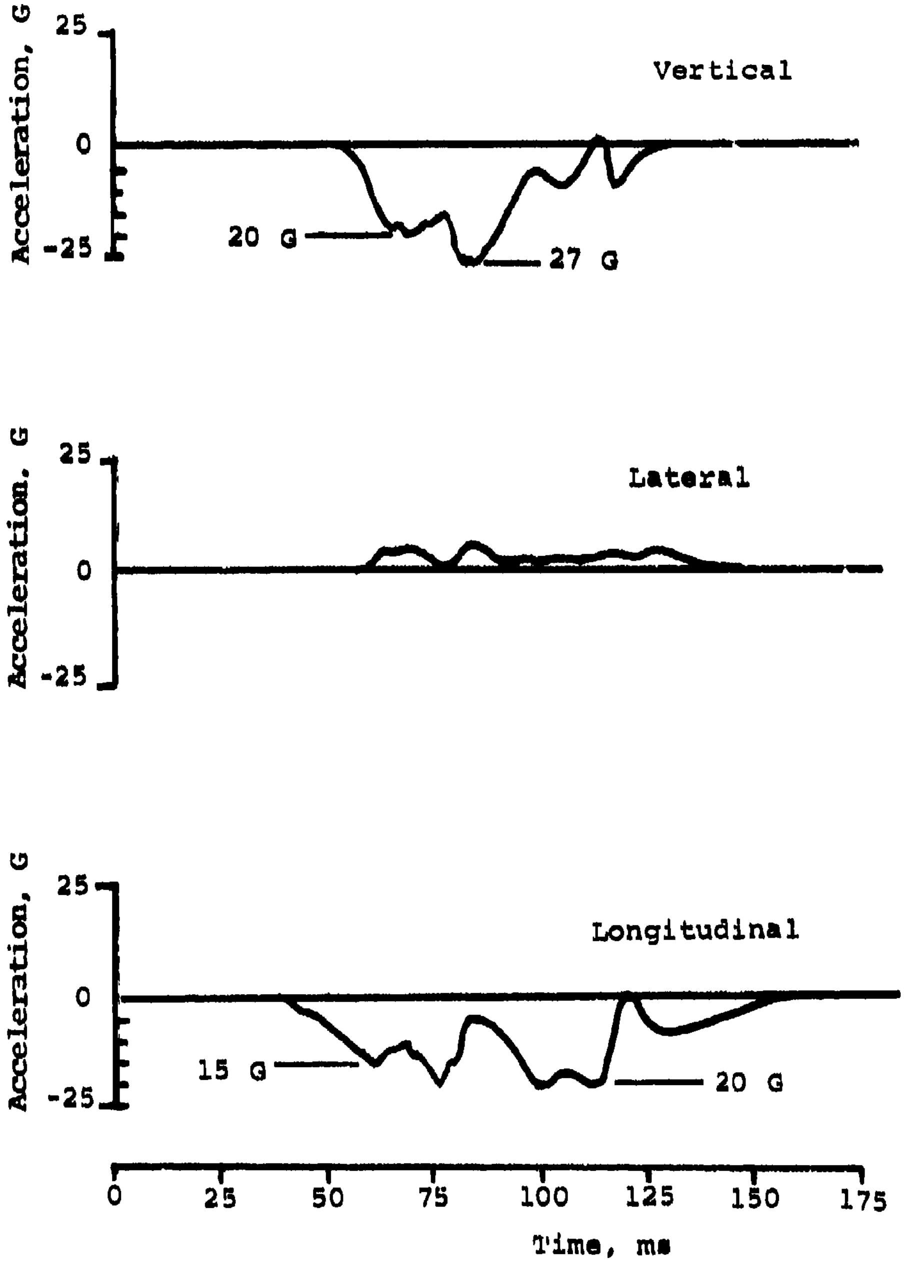


Figure 100. Test 2C - Vertical, longitudinal, and lateral acceleration, dummy pelvis.

Test 1B - Forward-Facing Seat, Three Axis Loading

A modified forward-facing seat with new configuration vertical attenuators was installed in the dynamic test fixture in a manner similar to Tests 1 and 1A. A 50th percentile clothed dummy with combat equipment weighing 204 lb was restrained in the seat (Figure 101). The seat was oriented to simulate 30 degrees pitch down and 10 degrees of roll, then was rotated back 90 degrees so that a vertical drop could be simulated on the horizontal accelerator sled. The sled was accelerated and a velocity of 46.6 fps was achieved at the time of impact. This was 4.6 fps above the desired 42 fps.

A visual inspection of the seat after the test revealed that the vertical energy attenuators had stroked only 6.1 in.; a minimum stroke of 11 in. had been anticipated (Figure 102). The rear tube of the seat pan had been bowed downward 2.8 in. at the center (Figure 102). The cause of the minimum stroke was initially attributed to much of the energy being absorbed by deformation of the rear tube. However, review of the motion picture film revealed the cause of the minimal stroke. Vertical impact was simulated using a horizontal accelerator by rotating the seat 90 degrees onto its back. The legs of the dummy were held up by light string; during impact the string broke, allowing the legs to fall down under the seat, thereby preventing the seat from fully stroking. The impact of the front of the seat pan on the calves of the dummy's legs was evidenced by marks (Figure 103). No other damage was detected on the seat structure or fabric.

A review of the instrumentation data showed that the maximum impact acceleration recorded on the sled was 46 G. The calculated peak acceleration was 54.2 G for the time base of .052 second (Figure 104). Accelerations measured on the chest and pelvis showed the effectiveness of the new vertical attenuator configuration. The initial acceleration overshoots experienced on previous vertical impact tests was reduced to a plateau which did not exceed 17 G on both the pelvis and chest (Figure 105). Subsequent overshoot occurred on the pelvis and chest reaching peaks of 36 G and 28 G respectively. These accelerations were attributed to impact of the seat pan with the dummy's legs. Restraint system forces were minimal due to the predominantly vertical impact, and diagonal-strut forces did not reach the stroking threshold load because of the seat interference with the dummy's legs.

The test conclusion reached was that the principal objective, determining the effect of the new attenuator configuration, was accomplished. Initial peak accelerations were flattened as required during the initial stroking period, and this data was not affected by the subsequent seat contact with the dummy's legs.

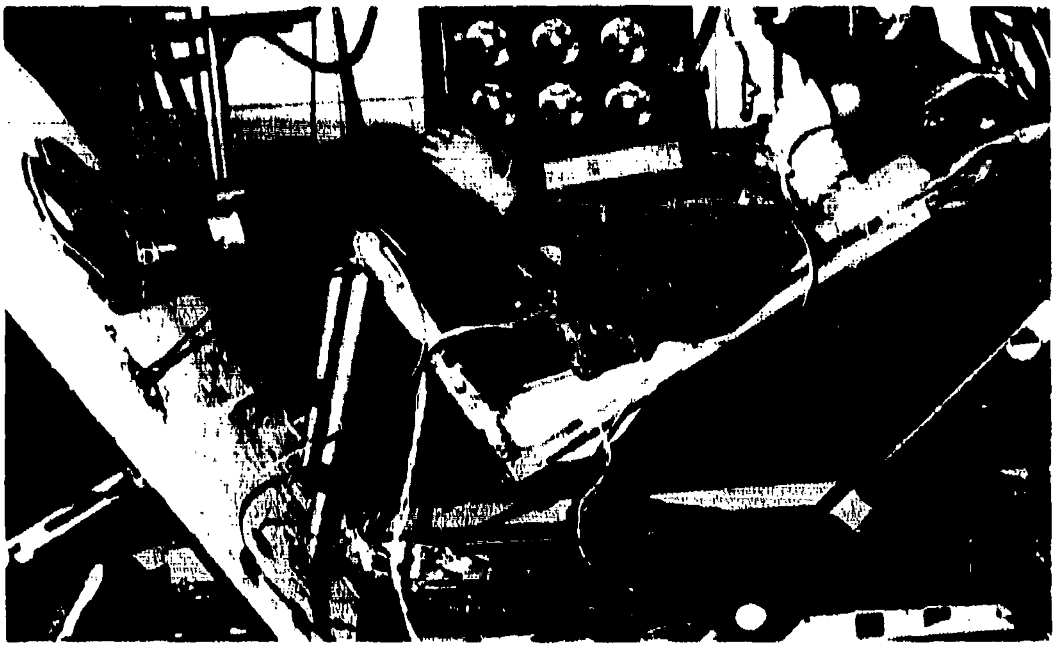


Figure 101. Pre-test 1B - Three-axis loading.

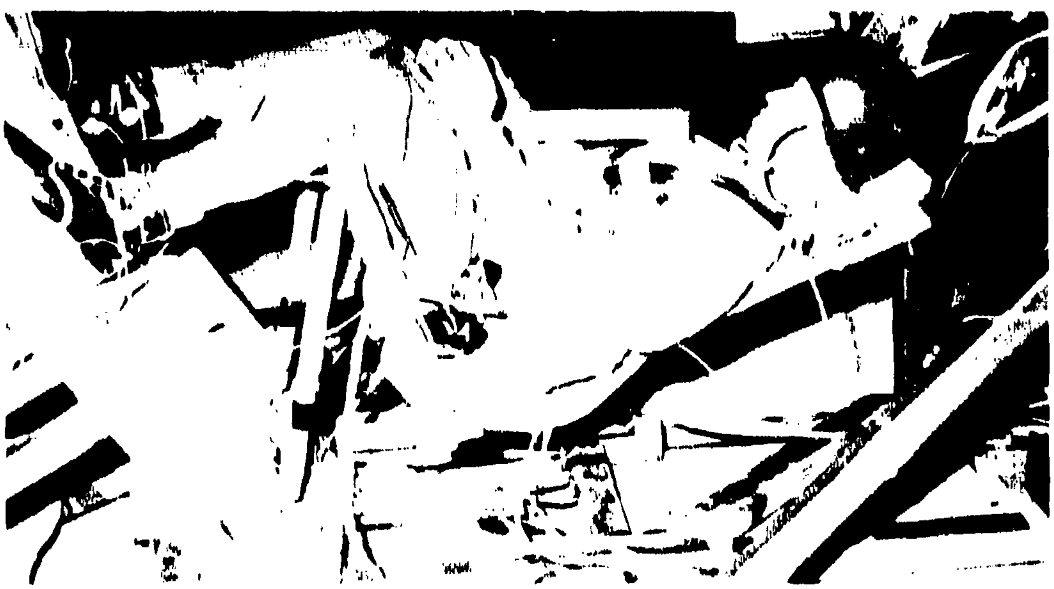


Figure 102. Post-test 1B - Three-axis loading.

←Impact with dummy's legs

Figure 103. Seat impact with dummy's legs.

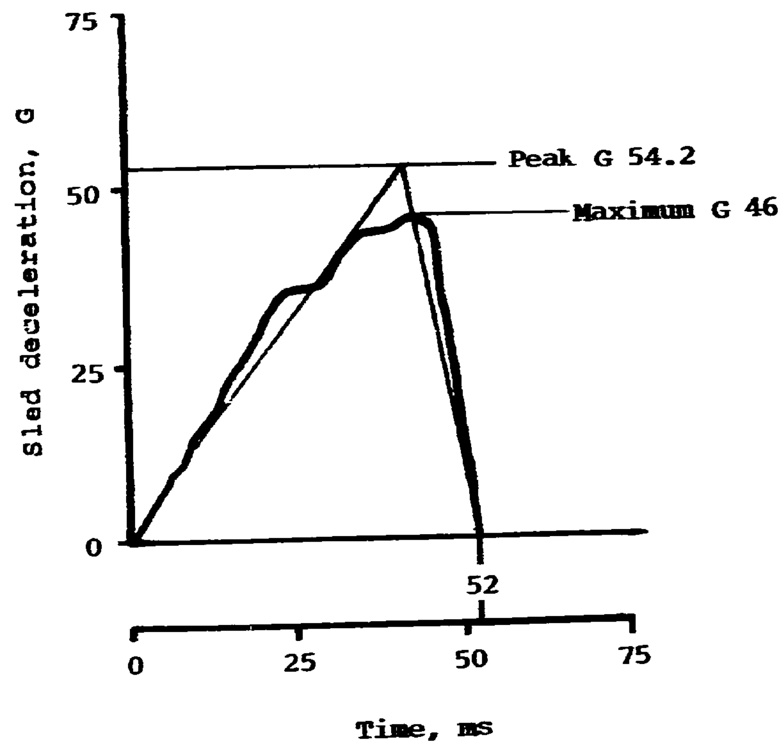


Figure 104. Test 1B - Sled deceleration time history.

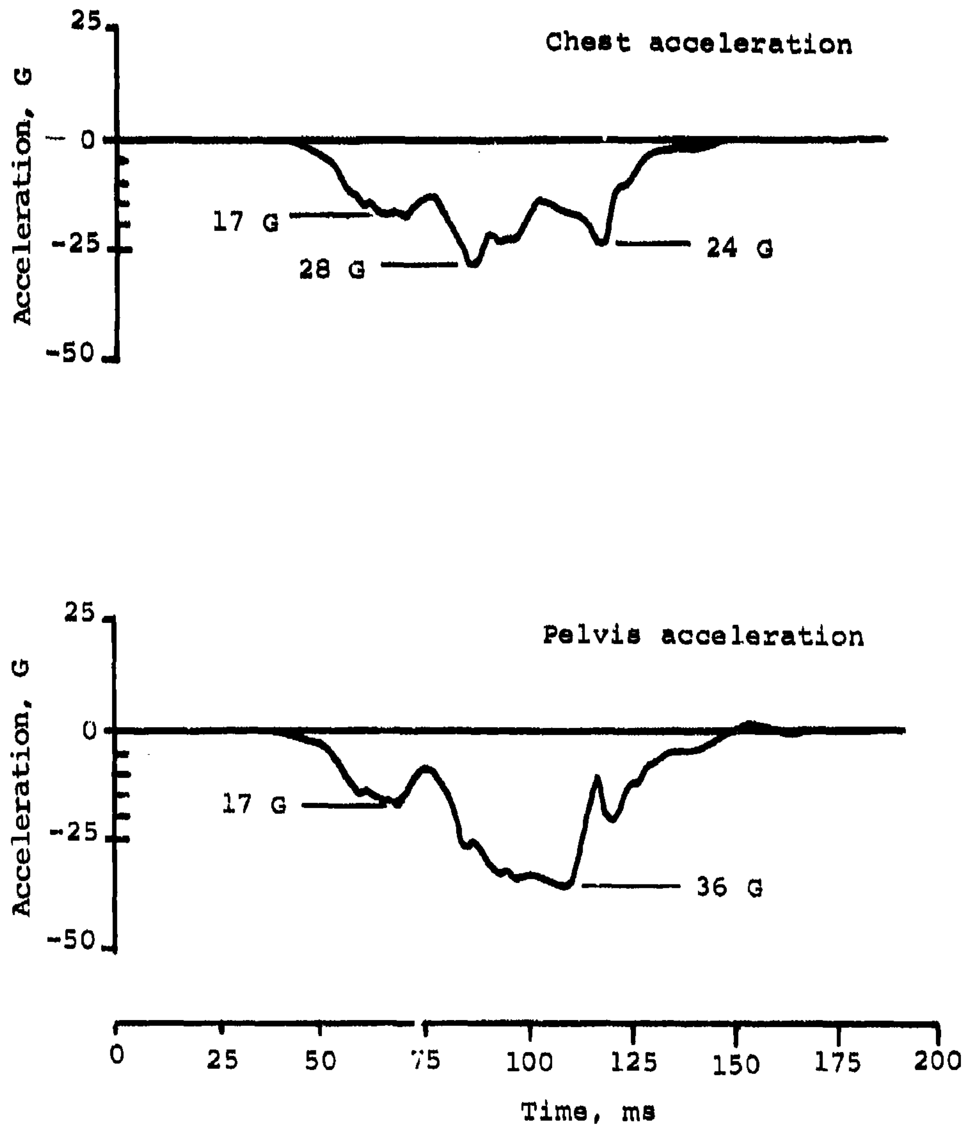


Figure 105. Test 1B - Vertical acceleration, dummy pelvis and chest.

CONCLUSIONS

The crashworthy troop seat testing program demonstrated that a light weight troop seat can be designed to reduce 95th percentile crash accelerations to within human tolerances. These seats and restraint systems weighed 17 lb and design optimization should reduce the weight to below 15 lb. The seat withstood dynamic test loadings without failure or deformation to an extent that would jeopardize the integrity of the seat, or would preclude retention of the occupant. Table 4 shows a summary of test results.

Overshoot excursions to 25G were recorded on predominantly vertical impact tests 2A and 2B using 95th and 50th percentile dummies. Dynamic Response Index (DRI) was 8 for the 95th and 19.4 for the 50th percentile dummy, giving a spinal injury probability of zero and 10 percent respectively (Reference 9, Figure 1-12). A 5th percentile dummy was not tested but an 18.9G plateau can be expected by extrapolating from the 12 and 14.5G of tests 2A and 2B. A reasonable DRI can be expected because overshoot levels were similar regardless of dummy size. Overshoot spikes can be reduced by refinement of seat design and testing procedures. In general, excursions above the specified plateau levels, which are within the time and acceleration limits for ejection seat design of the Eiband curve in TR71-22 (Reference 9), are acceptable.

Revisions to the testing criteria were required to permit successful conclusion of the test program. The criteria require the seat to be designed for a 50th percentile occupant who should not exceed an acceleration of 14.5 ± 1G in a vertical direction under a 42-fps impact, with a peak pulse of 48G. The criteria also require the seat to be designed for a predominantly vertical impact with forward and lateral components and impact velocity of 50 fps with a 95th percentile occupant. These requirements are not compatible with a ceiling-suspended seat, which will align itself along the resultant path and will stroke at the vertical impact setting. Insufficient stroking distance was available in the 17-in.-high seat. It was necessary to change the predominantly vertical impact requirements to agree with the pure vertical impact requirements, in order to prevent seat bottoming. Similar results can be achieved by maintaining the 50-fps impact velocity and reducing the acceleration from 48G to 34G. This pulse is attainable in aircraft designed with crashworthy landing gear.

TABLE 4. SUMMARY OF DYNAMIC TEST CONDITIONS

Test No.	Seat Type	Impact Attitude	Dummy Percentile	Total Weight (lb)	Impact Velocity (fps)	Peak G	Seat Stroke (in.)	Dummy Response (G) Plateau	Dummy Response (G) Overshoot	DRI @ time DRI	DRI @ time (ms)	Sled Stroke (in.)	Restraint Load (lb) Lap	Restraint Load (lb) Shoulder
1	fwd	3 axis	95th	243	49.3	48.6	10.75	14	67	37.6	120	23.5	400	700
2	aft	3 axis	95th	220	49.4	51.2	14.87	15	78	9.5	151	23.5	400	80
3	fwd	fwd yaw	95th	243	50.0	24.0	Lapbelt failure				246	40.0	750	2000
4	aft	fwd yaw	95th	243	50.0	24.0	Seat back failure			24.8	139	45.0	—	3000
1A	fwd	3 axis	95th	212	41.9	44.9	10.00	12	32	32.8	120	27.0	780	400
3A	fwd	fwd yaw	95th	243	49.5	23.6	6.80	15	23	11.7	155	45.0	2450	1320
4A	aft	fwd yaw	95th	243	48.5	26.2	8.00	19	21	18.0	129	43.0	—	--
2A	aft	3 axis	95th	220	42.3	52.5	11.00	12	25	8.0	162	25.5	—	--
2B	aft	3 axis	50th	170	42.2	52.4	11.00	14.5	25	19.4	105	25.5	—	--
2C	aft	3 axis	50th	204	49.0	60.9	12.10	19	25	24.5	109	—	—	--
1B	fwd	3 axis	50th	204	46.6	54.2	6.10	17	28	37.8	123	—	650	550

Notes:

Vertical attenuator load setting - 1450 lb.
Diagonal attenuator load setting - 1100 lb.
Total weight includes dummy, clothing, and equipment weights.
50th percentile dummy - Alderson Research Laboratory model VIP-50A.
95th percentile dummy - Sierra model 895.
Dummy response is chest acceleration except for test 1., which is pelvis acceleration.
Dummy response is vertical acceleration for 3-axis tests and longitudinal acceleration for fwd yaw tests.
Seat stroke is for vertical attenuator in 3-axis tests and longitudinal attenuator in fwd yaw tests.

The maximum loads recorded on the restraint systems, during normal tests were 2,450 lb on the lapbelt and 1,320 lb on the shoulder strap (Table 4). The draft Military Specification, Seat, Helicopter, Troop, specifies a design load of 4,000 lb on each strap. These loads are necessary to allow for a margin of safety and for reduction in strength due to aging. Ultimate strengths of 6,000 lb are established in the specification, primarily to obtain minimum elongation.

Component tests, static tests and dynamic tests were performed during seat development. Each was found to be necessary and cost effective in the orderly process of seat development.

RECOMMENDATIONS

A requirement of the crashworthy troop seat testing program was for the contractor to recommend appropriate modifications to the proposed draft specification MIL-S-XXXX(AV), Seat, Helicopter, Troop, and USAAMRDL TR 71-22, Crash Survival Design Guide. Recommended modifications to these documents follow.

DRAFT TROOP SEAT MILITARY SPECIFICATION CHANGE RECOMMENDATION

Changes were recommended to the draft specification titled MIL-S-XXXX(AV), Seat, Helicopter, Troop by AVSCOM, USAARL, USAAMRDL, and Boeing Vertol. These comments have been compiled and the original draft specification rewritten accordingly. The recommended reorganization of the specification and the numerous comments prohibited use of the normal procedure of cross hatching deleted items and underlining added items. The specification has been reproduced in the modified form.

The specification as presented, is still in a preliminary status and remains to be coordinated and finalized before it is officially released.

MILITARY SPECIFICATION

SEATS, HELICOPTER CABIN, CRASHWORTHY

GENERAL SPECIFICATION FOR

1. SCOPE

1.1 This specification establishes the design requirements for lightweight folding, crashworthy seats for use by troops/passengers in helicopters.

1.2 Classification. Seats shall be of the following types, classes, and sizes as specified (see 6.5):

Type 1	Passenger
Type 2	Troop
Class A	Forward-facing
Class B	Aft-facing
Class C	Side-facing
Size I	One man seat
Size II	Two man seat
Size III	Three man seat
Size IV	Four man seat

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of the invitation for bids or request for proposal form a part of the specification to the extent specified herein.

SPECIFICATION

Federal

V-T-295	Thread, Nylon
QQ-P-416	Plating, Cadmium (Electrodeposited)
QQ-Z-235	Zinc Coating, Electrodeposited, Requirements for

PPP-B-601	Boxes, Wood, Cleated-Plywood
PPP-B-621	Boxes, Wood, Nailed and Lock-Corner
PPP-B-636	Boxes, Fiberboard

Military

MIL-P-116	Preservation, Methods of
MIL-D-1000	Drawings, Engineering and Associated Lists
MIL-C-7219	Cloth, Duck, Nylon, Parachute Packs
MIL-A-8625	Anodic Coatings, for Aluminum and Aluminum Alloys
MIL-R-8236	Reel, Shoulder Harness, Inertia Lock
MIL-W-8604	Welding of Aluminum Alloys: Process for
MIL-F-8905	Adapter, Tie Down, Aircraft Floor
MIL-W-25361	Webbing, Textile, Polyester, Low Elongation

STANDARDS

Federal

FED-STD-505	Colors
FED-STD-751	Stitches,Seams, and Stitchings

Military

MIL-STD-22	Weld-Joint Designs
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of US Military Property
MIL-STD-143	Specifications and Standards, Order of Precedence for the Selection of
MIL-STD-471	Maintainability Demonstration
MIL-STD-785	Reliability Program for Systems and Equipment Development and Production
MIL-STD-810	Environmental Test Methods
MIL-STD-831	Test Reports, Preparation of
MIL-STD-889	Dissimilar Metals
MIL-STD-1186	Cushioning, Anchoring, Bracing, Blocking, and Waterproofing; with Appropriate Test Methods
MIL-STD-1261	Welding Procedures for Constructional Sheets
MIL-STD-1290	Light Fixed- and Rotary-Wing Aircraft Crashworthiness

PUBLICATION

MILITARY HANDBOOK

MIL-HKBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures

REPORTS

USAAMRDL TR 71-22	Crash Survival Design Guide
U.S. ARMY Natick Labs TR 72-51-CE	The Body Size of Soldiers

(Copies of specifications, standards, publications, and reports required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Specification sheets. The individual item requirements shall be as specified herein and in accordance with the applicable specification sheets. In the event of any conflict between requirements of this specification and the specification sheet, the latter shall govern.

3.2 First article. Unless otherwise specified, the seat furnished under this specification shall be a product which has been inspected and has passed the first article inspection of 4.4.

3.3 Design chracteristics. The seat shall accommodate the specified type of occupant in the quantities identified for each respective size and orientation (see 1.2). The size 1 seat is the preferred configuration in order to avoid situations where the energy absorbers of a multi-unit seat are rendered ineffective due to less than full occupancy. To the maximum extent practical, seat classes (see 1.2) shall be interchangeable to enhance standardization. Seating should be aft-facing whenever operational requirements permit. Forward-facing is the next preference. Seating shall not be side-facing unless absolutely necessary for operational considerations. It is desirable that all seats face in the same direction so that the seat backs protect occupants from loose equipment which can become flying projectiles during crash impact.

3.3.1 Seating surface. The seat bottom and back shall be designed for comfort and durability. Seat bottoms made of fabric shall be provided with means of tightening to compensate for sagging in use. Sufficient clearance between fabric backs and bottoms shall be provided to preclude body contact with seat structure when subjected to the specified loads (see 3.6). Headrests may be provided to prevent contact between occupant's head and seat structure. To accommodate back and butt packs, that troops may be wearing, the backs of Type 2 seats shall be convertible without tools, to provide the recess shown in Figure 1. Maximum time to convert either way shall not exceed 10 seconds, and both back supports shall meet the strength requirements.

3.3.2 Crash resistance. The seat shall prevent the 5th through 95th percentile occupants (see 6.3.1) from experiencing vertical decelerations in excess of human tolerance (see Figure 2) during crash pulses of the severity shown in Figure 3 and not experience structural failure. Energy shall be absorbed in the vertical axis by load-limiting devices. The energy-absorption stroke shall be the maximum attainable in the space between the seat bottom and the aircraft floor. In any case, not less than 14 inches of vertical stroking distance shall be provided when measured at the occupant's center of gravity. The seat and restraint shall minimize occupant submarining (see 6.3.5) and dynamic overshoot (see 6.3.6).

3.3.3 Seat attachment. Acceptable means of attaching seats to the cabin interior are ranked below in order of desirability:

1. Suspended from the ceiling with attenuators, and wall stabilized.

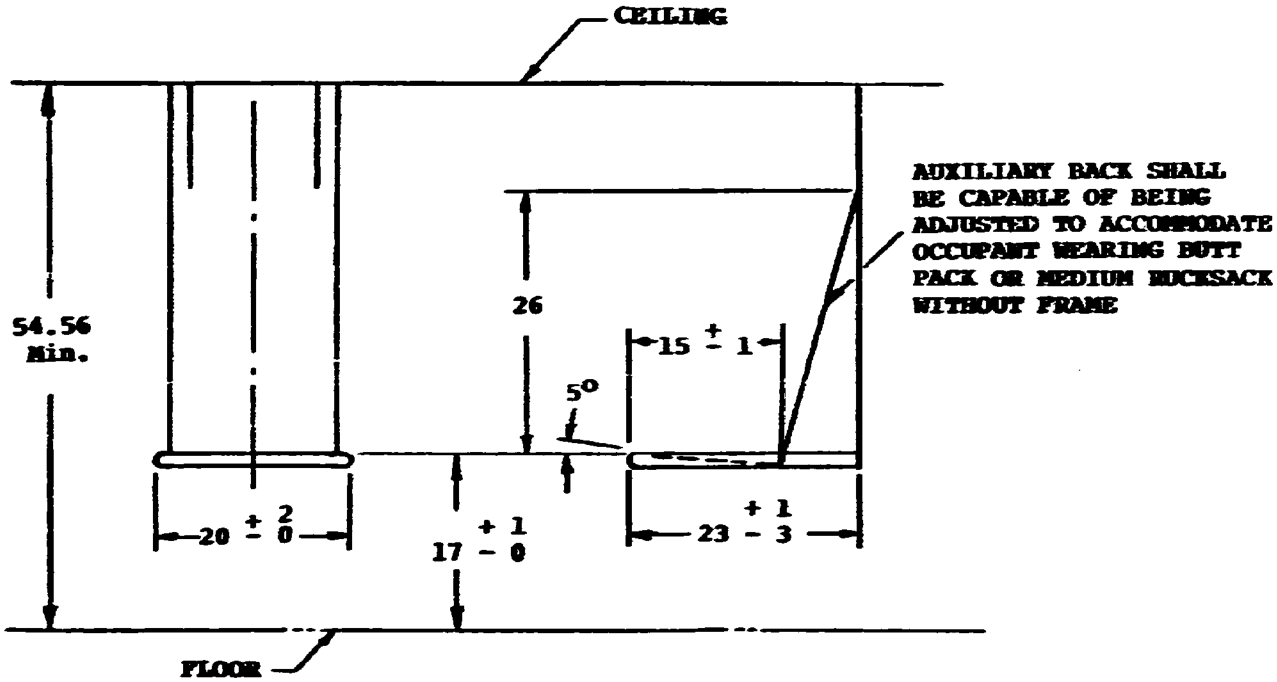
2. Suspended from the ceiling with attenuators, and floor stabilized.

3. Wall mounted with attenuators.

4. Floor mounted with attenuators.

5. Ceiling and floor mounted (vertical energy attenuators above and below seat).

3.3.3.1 Attachment distortion. Seat attachments shall be capable of accommodating crash induced cabin distortion consisting of four inch vertical displacement and a 10° misalignment of any attachment.



NOTE: ALL DIMENSIONS IN INCHES

Figure 1. Seat dimensions.

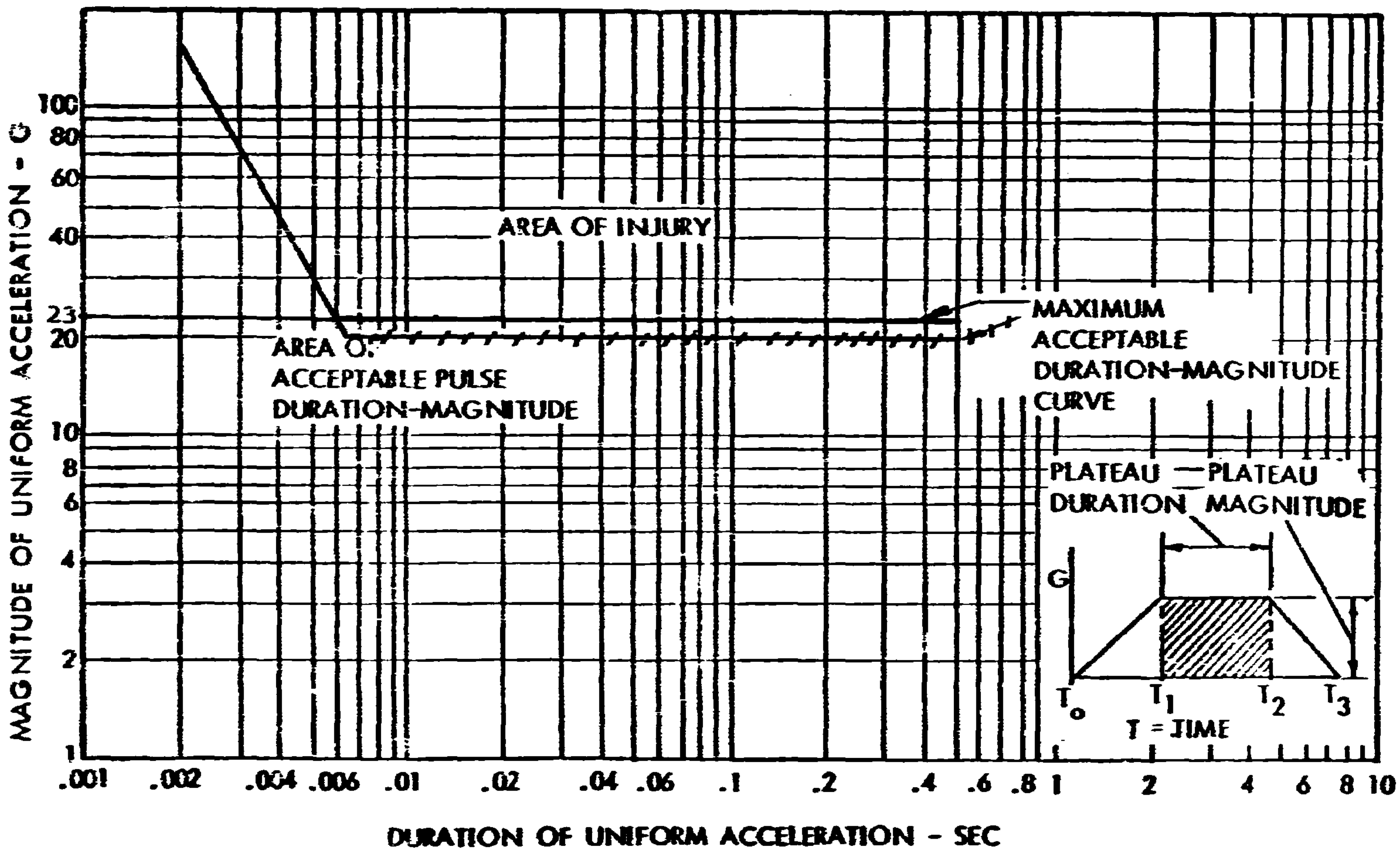


Figure 2. Maximum acceptable vertical pulse acceleration and duration values.

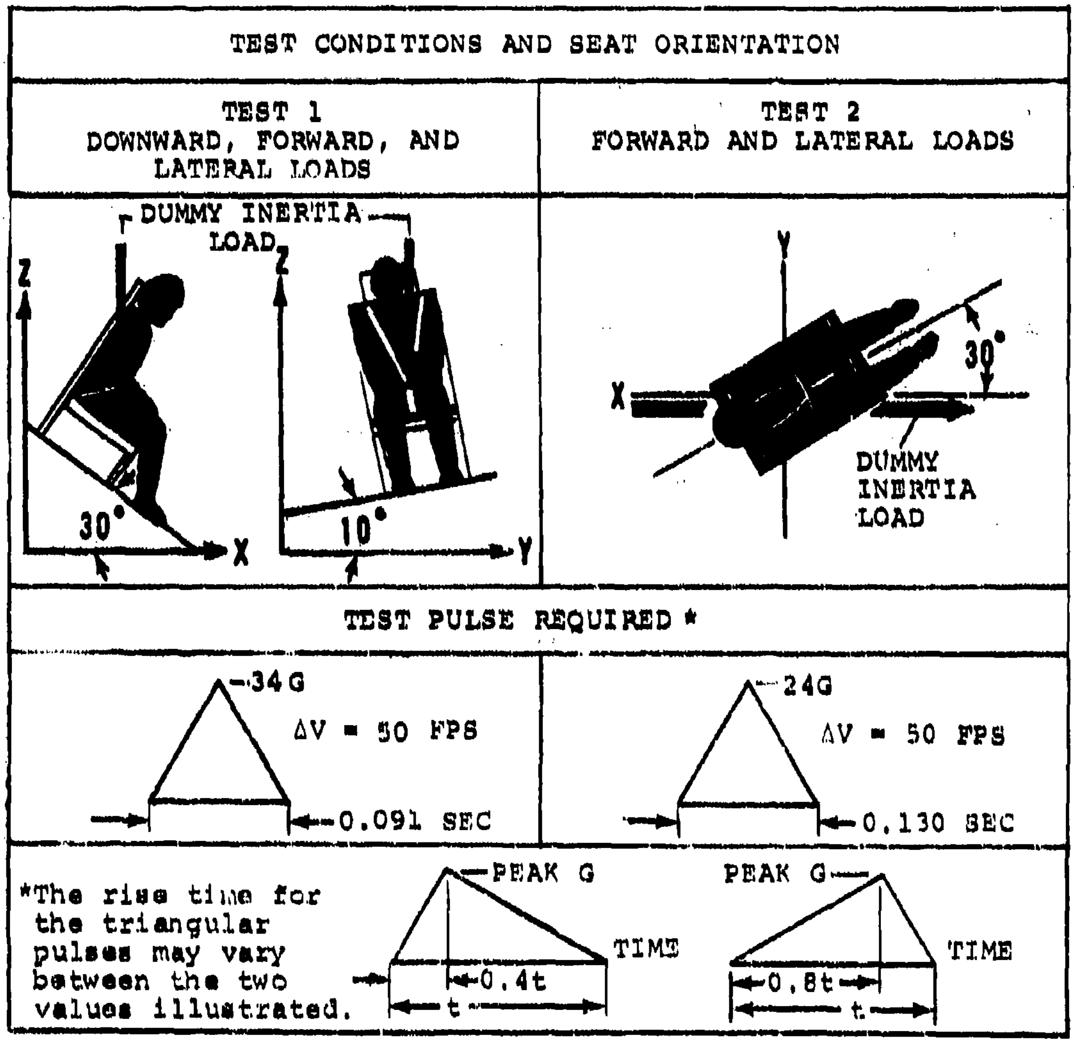


Figure 3. Dynamic test requirements.

3.3.4 Seat folding & stowing. Seats shall be so designed that they may be quickly removed or folded and secured. Tools shall not be required.

3.3.4.1 Seat disconnect time. The time for disconnecting each Size I seat (one-man seat) by one man shall not exceed 20 seconds. The time for disconnecting multi-unit seats by one man shall not exceed 20 seconds multiplied by the size number.

3.3.4.2 Folding and stowage. Each seat shall be capable of being folded, stowed, and secured or unstowed quickly and easily by one man in a period not to exceed 20 seconds multiplied by the seat size number.

3.3.5 Obstructions. Seat suspension or mounting shall not interfere with rapid ingress or egress. Braces, legs, cables, straps, and other structures shall be designed to prevent snagging or tripping. Loops shall not be formed when the restraint system is in the unbuckled position.

3.3.6 Occupant restraint. The seats shall have an integral restraint system with lap belt and self-retracting and self-locking shoulder harness for each seating position. The restraint shall be comfortable, light in weight, and easy for the occupant to put on and remove. Reduction in support of the occupant shall not occur due to stroking of the energy absorbers or deformation of the seat. Strap slippage shall be prevented by proper design of adjusters and webbing material selection.

3.3.6.1 Lap belt. The lap belt anchorage geometry shall be as shown on Figure 4. The lap belt anchor fittings shall be attached to the stroking portion of the seat and shall be capable of displacing plus or minus 30 degrees vertically. These fittings shall also be capable of withstanding lateral loads when the webbing is pulling at an angle of plus or minus 60 degrees to the normal plane of the fitting. Lap belt retractors may be used in lieu of adjustors. In any event, lap belts shall be prevented from falling behind or below the seat. Flexible standups shall be provided at the lap belt anchor points to project the lap belt upward and forward 5 inches for easy reach. Retractors or adjustors shall not be located over hard points of the occupant's skeletal structure. The force required to adjust the webbing length shall not exceed 3 lbs and it shall be possible for the seated occupant to easily adjust with either hand. If retractors are used, they shall not pull with more than 3 lbs force, and shall ratchet in increments not to exceed 0.5 in.

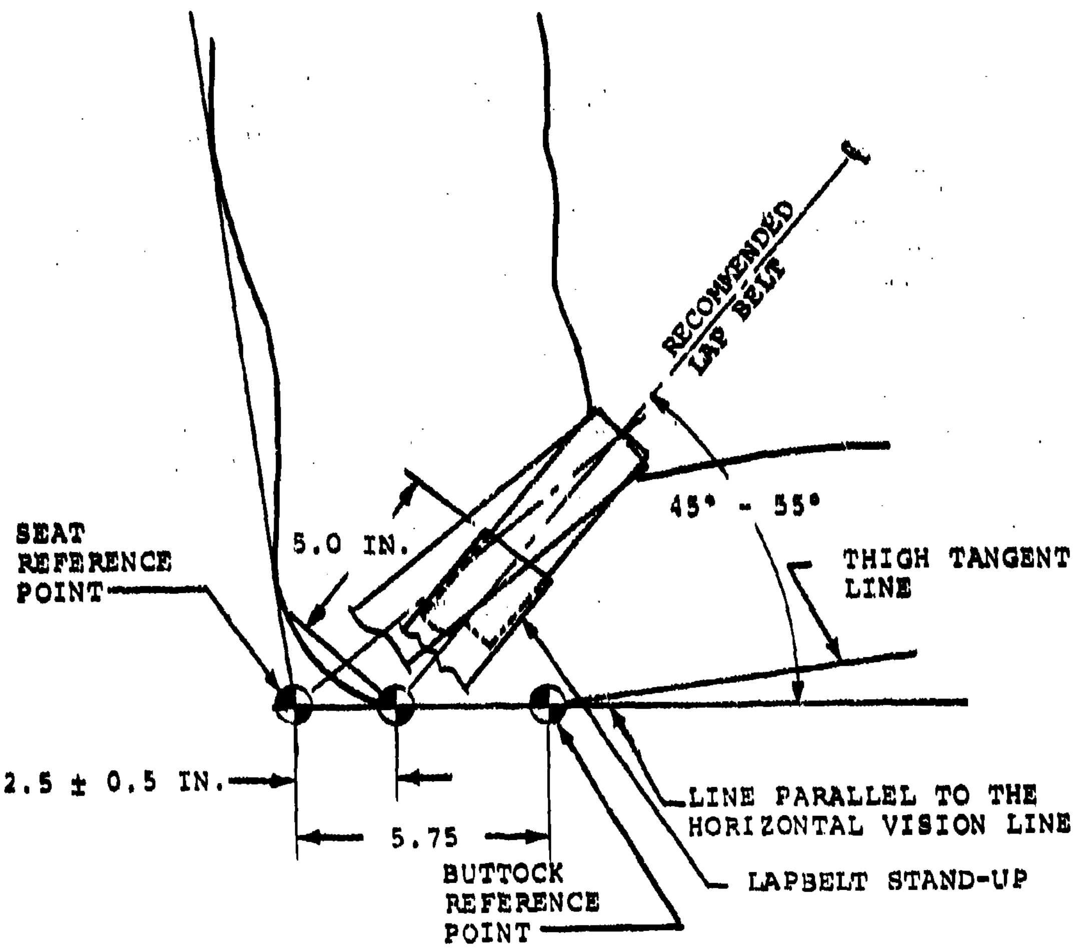


Figure 4. Lapbelt anchorage geometry.

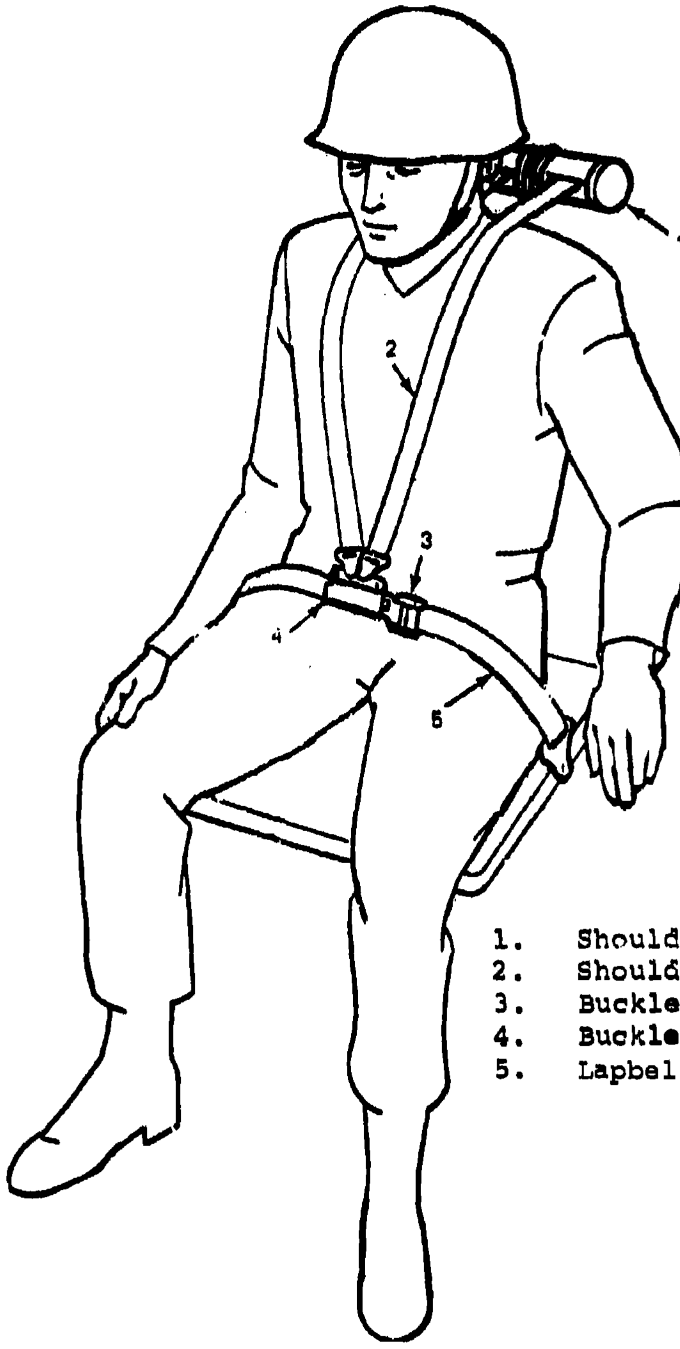
3.3.6.2 Shoulder straps. Forward facing seats shall be provided with the double shoulder strap configuration shown in Figure 5. For aft and side facing seats, the diagonal shoulder strap configuration shown in Figure 6 shall be used. Shoulder harness anchorage geometry shall conform to Figure 7. The anchorage or guide at the top of the seat shall not permit more than 0.5 inch lateral movement of the strap at this point. Distance between the inner edges of the shoulder straps at the seat back shall be within 3 to 5 inches. Flexible guides shall be provided on the seat back as shown on Figure 7 to project the shoulder strap fittings up and forward on the seat back for easy reach.

3.3.6.3 Inertia reel. Shoulder strap inertia reel or reels shall be provided which pull with not more than 3 lbs force and will fully retract the shoulder strap or straps to shoulder height in the guides described above. The reel shall be of a type which remains locked after it locks up initially, as per the locking requirements stated in MIL-R-8236 and must be manually reset by a device on the reel. The reel shall be located on the seat close to the shoulder strap guide point at the back of the seat to minimize strap elongation.

3.3.6.4 Restraint buckle. The restraint harness buckle shall be of the quick-release type and require intentional motion by the occupant to activate it. The buckle shall be capable of being operated with a gloved hand as well as with one finger of either hand while tension equal to the occupant's weight is supported by the harness. The force required to release it normally, as well as post crash and under the previous condition, shall not be less than 15 pounds nor more than 25 pounds. The buckle shall be of a lift lever release configuration. Lap belt and shoulder strap fittings shall be ejected simultaneously when the lever is lifted, even when there is no load on the restraint straps. The lap belt shall be capable of connection without connecting the shoulder straps. The release buckle shall be guarded to prevent jamming of the mechanism by clothing or equipment worn by the seat occupant causing inadvertent release.

3.4 Construction.

3.4.1 Critical members. All critical compressive structural members shall be fabricated from ductile materials having a characteristic value of not less than 5 percent elongation. All critical tensile and bending members shall be capable of elongating a minimum of 10 percent prior to failure.



1. Shoulder Strap Reel
2. Shoulder Strap
3. Buckle Link
4. Buckle
5. Lapbelt

Figure 5. Forward- and aft-facing seat restraint system configuration.

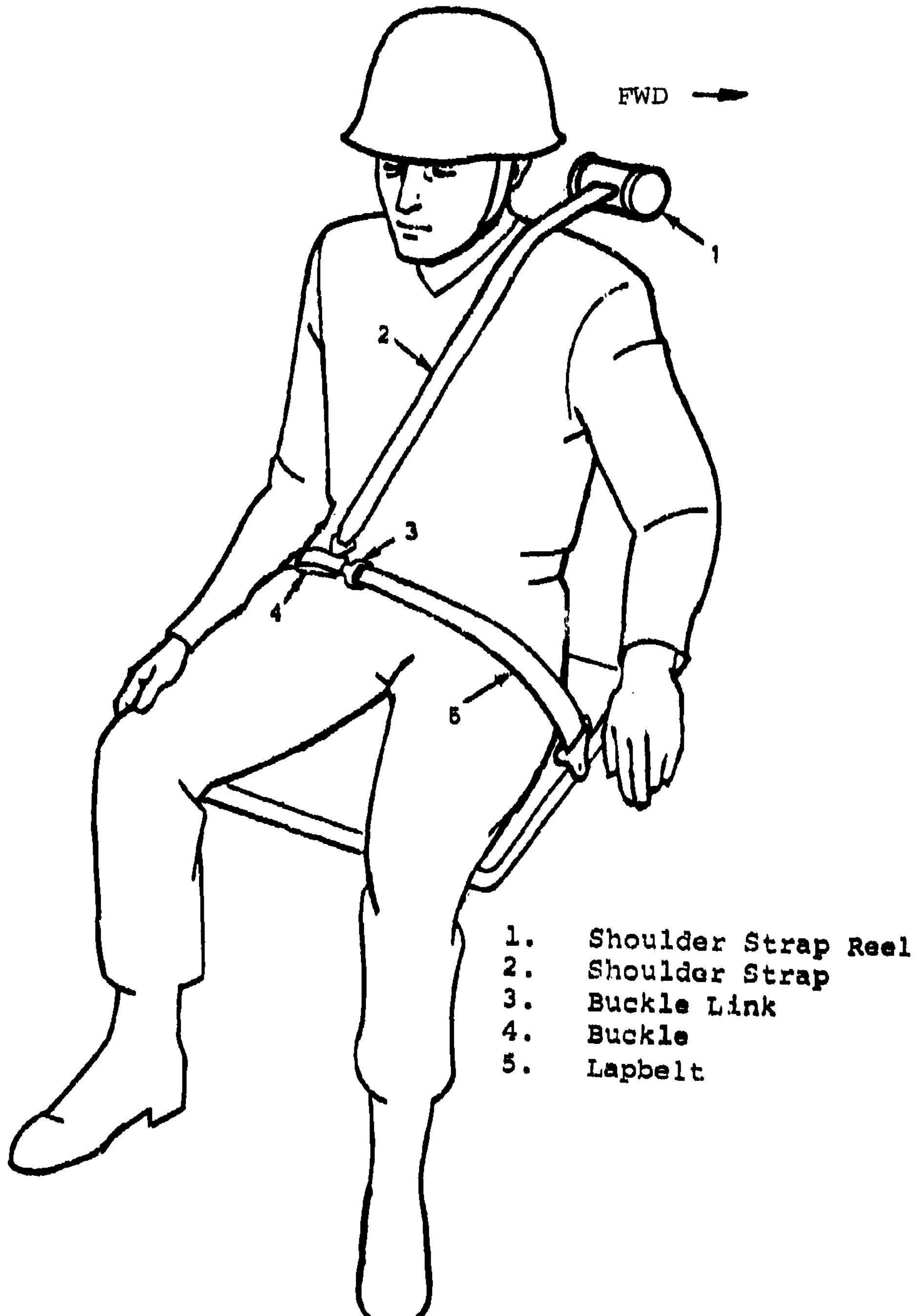


Figure 6. Side-facing seat restraint system configuration.

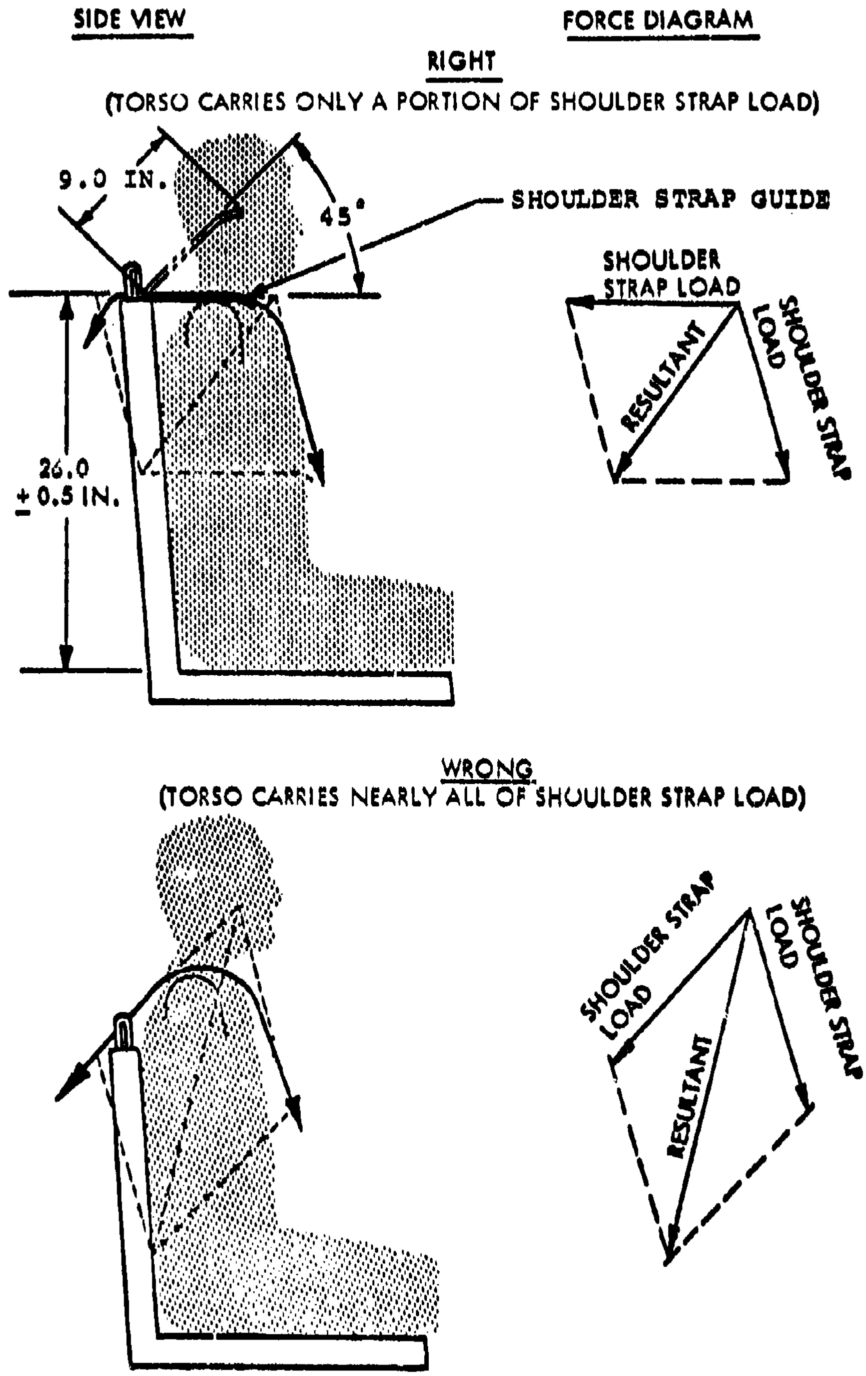


Figure 7. Shoulder harness anchorage geometry.

3.4.2 Dissimilar metals. Unless components are suitably protected against electrolytic corrosion, contact between dissimilar metals shall not be used where it is feasible to avoid it. Dissimilar metals are defined in MIL-STD-889.

3.4.3 Castings. Castings used in the seat shall conform to MIL-C-6021.

3.4.4 Heat treatment. Heat treatment of aluminum and steel parts shall conform to MIL-H-6088 and MIL-H-6875, respectively.

3.4.5 Structural connections. Safety factors shall be 5 percent and 10 percent for shear and tensile bolts, respectively. Bolts less than 0.25 inch in diameter shall not be used in tensile applications. Riveted joints shall be designed in accordance with MIL-HKBK-5. Welding shall be in accordance with MIL-W-6873, MIL-W-8604, MIL-W-45204, MIL-STD-22, and MIL-STD-1261.

3.4.6 Joining and Fastening. Fittings and joints requiring disassembly for maintenance shall be bolted. All thread and stitches used for sewing seat back and seat bottom shall be in accordance with V-T-295 and FED-STD-751, Type 301, respectively.

3.4.7 Standard parts. MS or AN standard parts shall be used wherever they are suitable for the purpose.

3.4.8 Restraint construction.

3.4.8.1 Stitch pattern and cord size. Stitch pattern and cord size shall sustain a minimum of 100 pounds per inch of stitch length, and shall comply with Figure 8.

3.4.8.2 Wrap radius. The wrap radius shall be the radius of the fitting over which the strap is wrapped at buckles and anchorages, as shown on Figure 9. The strap wrap radius shall be not less than 0.062 inch.

3.4.8.3 Hardware-to-strap folds. Figure 10 illustrates a recommended method to reduce the weight and size of attachment fittings by folding the strap at anchorage buckle fittings.

3.4.8.4 Surface roughness of fittings. Fittings in contact with the straps shall have a maximum surface roughness of RMS-32.

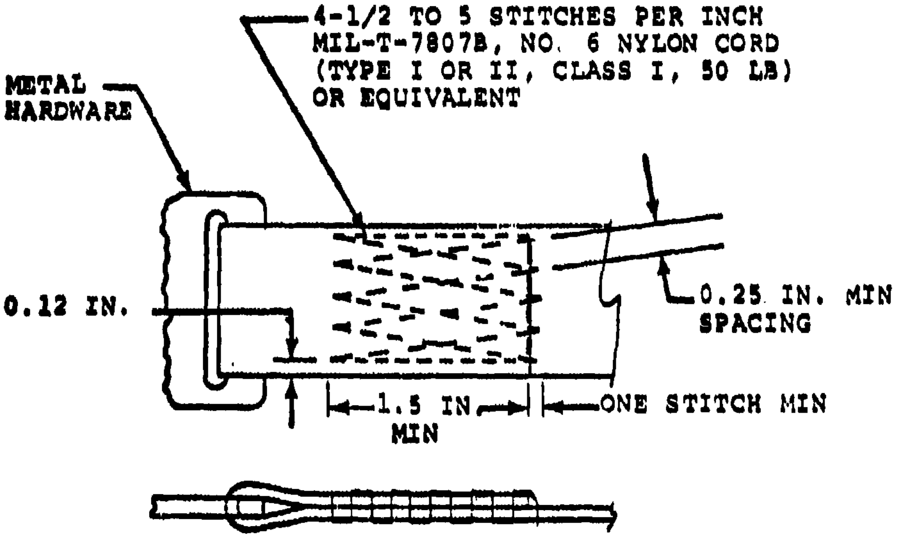


Figure 8. Stitch pattern and cord size.

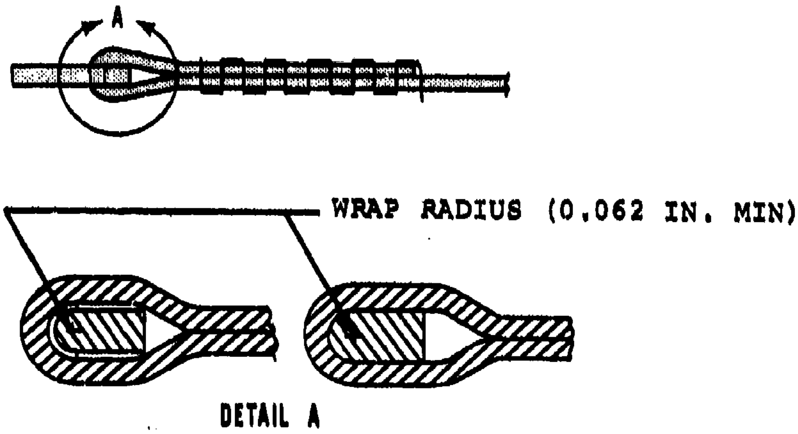


Figure 9. Wrap radius for webbing joints.

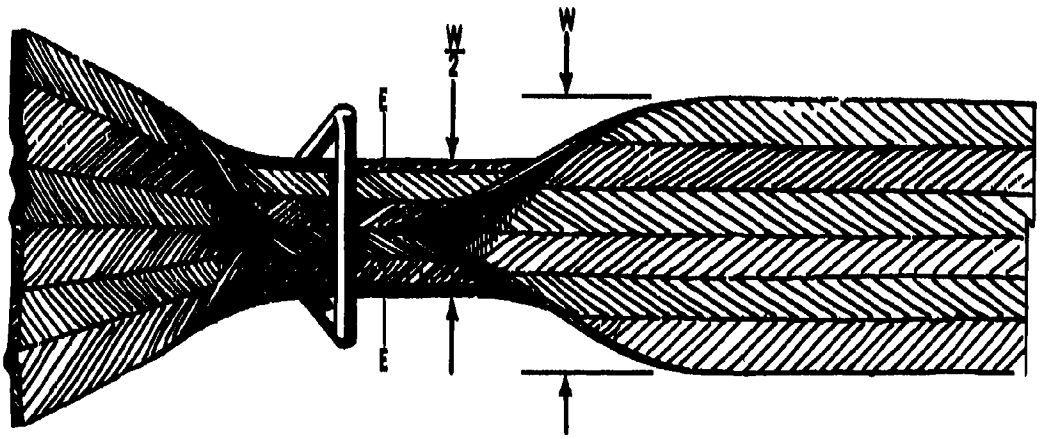


Figure 10. Webbing fold at metal hardware attachment.

3.5 Weight. The complete seat of each size, including the restraint shall not exceed the weights tabulated below:

Size of Seat	Weight (lb)
I	15
II	30
III	45
IV	60

3.6 Structural strength and deformation. Longitudinal, lateral, and upward seat structural strength and deformation requirements are based on the 95th percentile clothed and equipped occupant weight of 242 lbs (see Table 1), plus the weight of the seat. Downward seat structural strength and deformation requirements are based on the effective weight of the 50th percentile clothed and equipped occupant, plus the weight of that portion of the seat which must stroke during vertical crash force attenuation. Table 1 lists the applicable weights.

TABLE 1. SEAT DESIGN AND STATIC TEST REQUIREMENTS

Test No.	Loading Direction with Respect to Aircraft axes	Load Factor	Weight (lb) Seat	Weight (lb) Occupant	Deformation
1	Forward	See Fig. 11	Total	242	See Figure 11
2	Aftward	12G Minimum	Total	242	No Reqmt.
3	Lateral, b	See Fig. 12	Total	242	See Figure 12
4	Downward	14.5±1G	Stroking portion	d	See Figure 13
5	Upward	8G Minimum	Total	242	No Reqmt.
6	Combined Forward, Downward, and Lateral, c, (See Fig.3, test 1)	14.5±1G	Stroking portion	d	See Figure 13

Notes:

a. One aircraft attachment shall be deformed vertically four inches and angularly ten degrees, prior to load application in each test.

b. The lateral loads shall be applied in the direction which is most critical. In the case of symmetrical seats, the loading direction is optional.

c. The forward and lateral loads shall be applied prior to the downward load application if distortions could impede vertical stroking.

d. 127 lb for Type 1 and 161 lb for Type 2.

3.6.1 Forward load. The seat shall have a static forward load deflection curve measured along the longitudinal (roll) axis of the aircraft which rises to the left and above the base area and extends into the acceptable seat failure area shown on Figure 11.

3.6.2 Aftward load. The seat strength shall be not less than 12G (see 6.3.4) for aftward loads measured along the longitudinal (roll) axis of the aircraft.

3.6.3 Lateral load. The seat shall have a static lateral load deflection curve measured along the lateral (pitch) axis of the aircraft which rises to the left and above the base curve and extends into the acceptable seat failure area shown on Figure 12.

3.6.4 Downward load. Human tolerance to vertical impact limits the allowable forces along the vertical axis of the aircraft and necessitates energy attenuation. The seat shall have a downward load-deflection curve measured along the vertical (yaw) axis which falls within the acceptable area on Figure 13.

After the seat has stroked through the available stroking distance, the seat bottom shall be supported on the floor.

3.6.5 Upward load. The seat strength upwards shall not be less than 8G parallel to the vertical axis.

3.6.6 Restraint design loads. Strength and elongation properties of the restraint shall conform to Table 2.

TABLE 2. RESTRAINT LOAD - ELONGATION REQUIREMENTS

Use	Minimum Strap Width (in$\pm$0.10)	Minimum Thickness	Maximum Elongation at Design Load (percent)	Design Load (lb)	Minimum Breaking Strength (lb)
Lapbelt	2.25	.045	7.5	4,000	6,000
Double or Single Shoulder Straps-Each	2.00	.045	7.5	4,000	6,000

NOTE: All loads are applied in straight tension

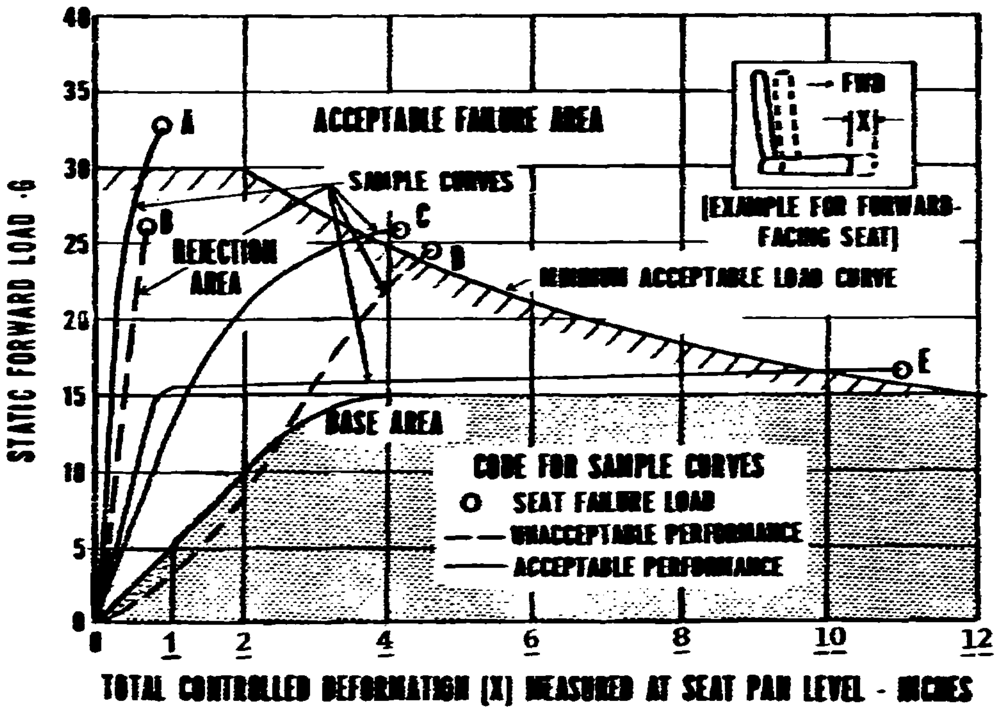


Figure 11. Seat forward load and deflection requirements.

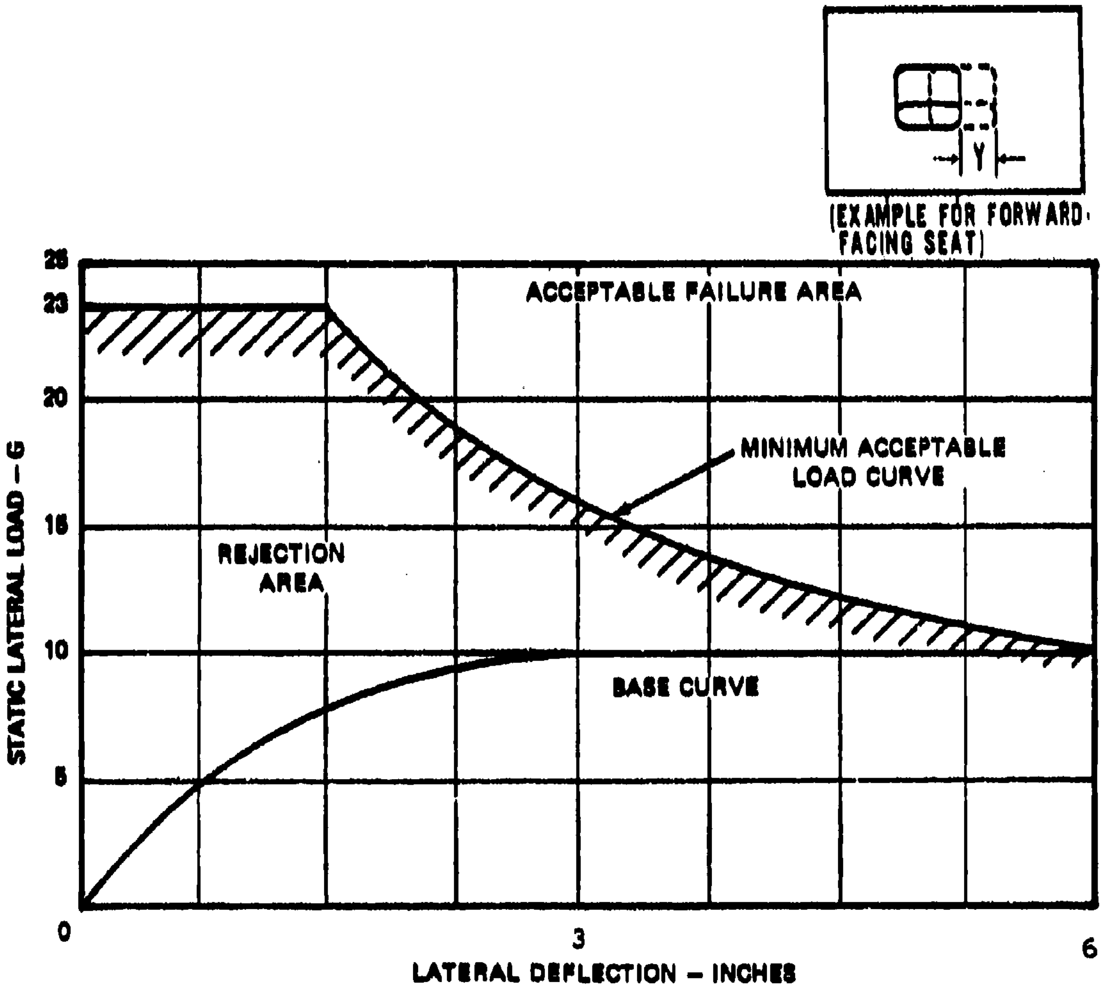


Figure 12. Lateral seat load and deformation requirements.

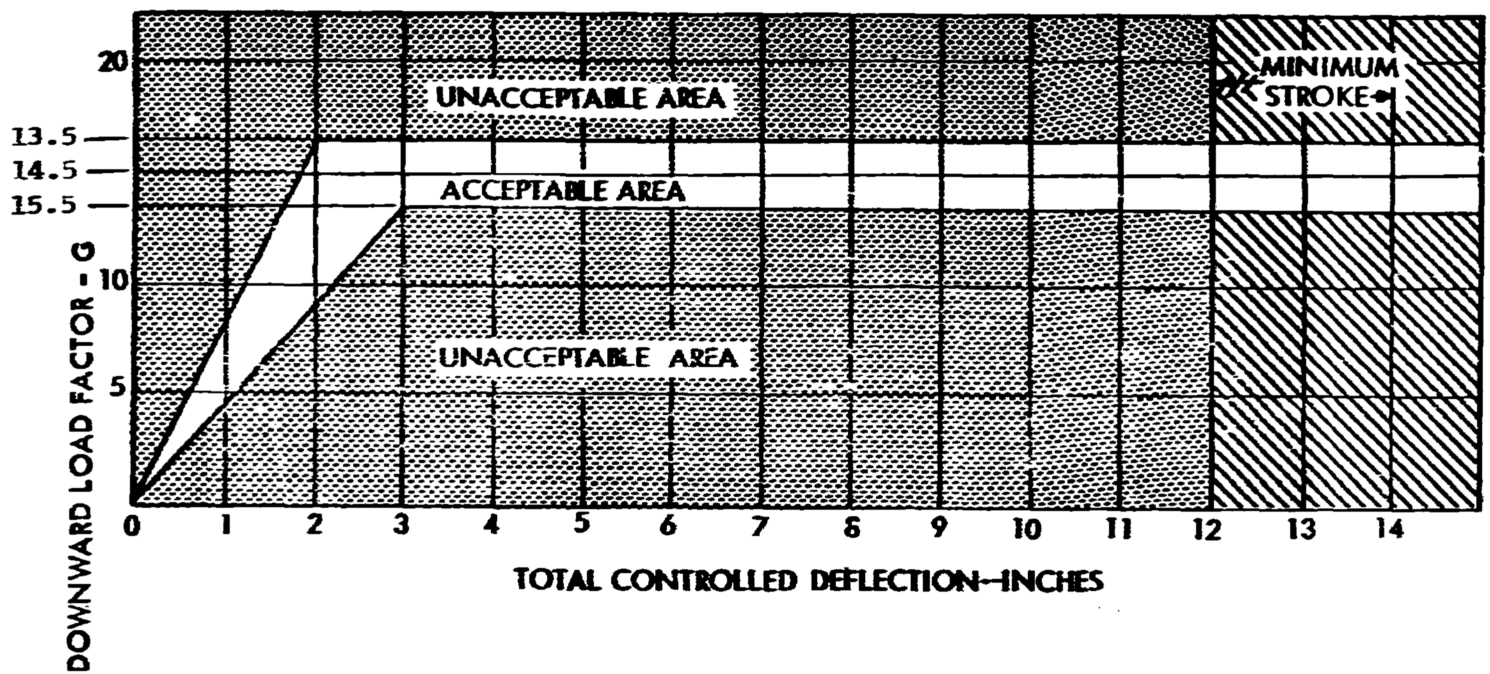


Figure 13. Seat downward load and deflection requirements for 50th percentile.

3.7 Materials. When specifications and standards are not specifically designated, selection of materials and processes shall be in accordance with MIL-STD-143. Materials that are nutrients for fungi shall not be used when it is feasible to avoid them; where used and not hermetically sealed, they shall be treated with a fungicidal agent.

3.7.1 Flammability and Toxicity. Materials which support a self-sustained combustion and materials which, when burned or exposed to high temperatures give off toxic fumes, shall not be used.

3.8 Reliability. Except for fabric parts, the minimum life of all seat components subjected to normal wear and tear shall be 5,000 hours of aircraft operation and 5,000 adjustments. Deterioration and wear of fabric parts shall be limited so as to meet minimum strength requirements after five years of use, and possess unlimited shelf life.

3.9 Maintainability. The seat shall require no scheduled maintenance other than the replacement of fabric components. The mean time to repair for both scheduled and unscheduled maintenance shall be less than .2 manhours.

3.9.1 Interchangeability and replaceability. Parts and assemblies of the seat shall be interchangeable or replaceable in accordance with MIL-I-8500.

3.9.2 Tools. Maintenance operations shall not require uncommon tools or special equipment.

3.10 Environmental Resistance. The seat with restraint system shall be capable of operating and of meeting the structural requirements of 4.6.2 after exposure to the following conditions.

3.10.1 Temperature. The seat shall deliver the specified operational and crashworthiness performance when subjected to the 4.6.4.1 and 4.6.4.2 temperature tests.

3.10.2 Sunshine. All nonfabric materials shall show no evidence of any degrading effect when subjected to the 4.6.4.3 sunshine test.

3.10.3 Humidity. The seat shall withstand the humidity test specified in 4.6.4.4.

3.10.4 Fungus. If any material utilized in the construction of the seat is suspected to be a nutrient to fungi, the material shall show no deterioration when subjected to fungus tests in accordance with 4.6.4.5.

3.10.5 Salt fog. All materials used in the construction of the seat shall withstand the salt fog test of 4.6.4.6.

3.10.6 Dust. The seat shall be capable of satisfactory operation after exposure to the dust test specified in 4.6.4.7.

3.10.7 Vibration. The seat shall be capable of satisfactory operation after being subjected to the vibration tests of 4.6.4.8. The occupied and unoccupied seat shall be free of resonance within the frequency range of the aircraft in which it will be used and no amplification shall occur.

3.11 System Safety. Maximum effectiveness and conservation of Army resources dictate a need for early identification, evaluation, and correction of system hazards. A system safety program shall be established by the contractor in accordance with MIL-STD-882 and implemented as directed by the procuring activity. The goal of the program shall be to insure that the optimum degree of freedom from hazard is effectively designed into the seat system.

3.12 Dimensions. Seats shall comply with the dimensions shown in Figure 1. Unless otherwise specified, a tolerance of ±1/16 inch will be allowed for seat overall dimensions. Restraint system webbing dimensions shall comply with Table 2 and Figures 5 and 6. The seat package, when it is in the stowed position, shall be held to a minimum size, not to exceed a thickness of six inches.

3.13 Finish.

3.13.1 Surface roughness. All exterior surfaces of the seat and restraint shall be free from both sharp edges and corners, or any other projections that could scratch the hands or clothing of the occupant.

3.13.2 Finishes. Aluminum alloy parts shall be anodized with MIL-A-8625, Type II. Magnesium alloy parts shall be treated in accordance with MIL-M-3171. Corrosive steel parts shall be either cadmium-plated in accordance with QQ-P-416, zinc-plated in accordance with QQ-Z-325, or chrome-plated in accordance with QQ-C-320.

3.13.3 Paint. The paint finish shall consist of one coat of zinc-chromate primer conforming to MIL-P-8585, followed by two coats of enamel conforming to TT-E-489.

3.13.4 Color. The seat and restraint color shall be in accordance with the cabin color scheme specified for the aircraft in which the seat will be used.

3.14 Identification of product.

3.14.1 Seat identification. A nameplate, permanently and legibly filled in with the following information, shall be securely attached to a permanent portion of the seat in a position capable of being read after the seat is installed. Marking shall be in accordance with MIL-STD-130 in 1/8 inch letters.

Seat, Helicopter, Cabin
Type (I or II as applicable)
Class (A,B, or C, as applicable)
Size (I, II, III, or IV as applicable)
Specification MIL-S-XXXX/X(AV)
National Stock No.________________
Manufacturer and Code________________
Contract or Order No.________________
Serial Number________________
U.S. Property

3.14.2 Restraint identification. Each individually replaceable strap shall have a permanent label attached. Each label shall contain the following information:

National Stock Number________________
Manufacturer and Code________________
Part number________________
Date of manufacture________________
Retirement date________________
Serial Number________________

3.14.3 Warning marking. The following warning shall be stenciled in 1/2 inch letters on the front of the seat back:

W A R N I N G

DO NOT STOW

EQUIPMENT

UNDER SEAT

3.15 Workmanship. The seat, including all parts, shall be constructed and finished in a thoroughly workmanlike manner. Particular attention shall be given to neatness and thoroughness of welding, riveting, machine-screw assemblies, and painting; freedom of parts from burrs and sharp edges; avoidance of unraveled edges of cloth; and straightness of stitched seams.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.2 Classification of inspections. The inspection requirements specified herein are classified as follows:

1. First article inspection (see 4.4)
2. Quality conformance inspection (see 4.5)

4.3 Inspection conditions. Unless otherwise specified, all inspections shall be performed under ambient environmental conoditions.

4.4 First Article Inspection. The first article inspection tests shall consist of all the tests specified under 4.6. Four seats of each type, class, and size are required for these tests, as a minimum.

4.5 Quality conformance inspections. Quality conformance tests shall consist of the following:

1. Visual examination
2. Functional test

4.5.1 Visual examination. Sampling shall be in accordance with MIL-STD-105, Inspection Level II, for the critical defects listed in Table 3, and Inspection Level I, for the minor defects. The acceptable quality levels are 1.5 and 2.5, respectively.

TABLE 3. CLASSIFICATION OF DEFECTS FOR VISUAL EXAMINATION OF THE SEAT	
CRITICAL	MINOR
1. Dimensions not within specified tolerances	201. Seat Marking - missing, insufficient, incorrect, illegible, or not permanent
2. Material imperfections	202. Seat color not as specified
3. Surfaces--misaligned or containing cracks, nicks, or other flaws	203. Defective exterior and interior markings on packaging
4. Any component missing, malformed, fractured, or otherwise damaged	204. Nonconforming packaging materials
5. Incorrect assembling or improper positioning of components	205. Inadequate packaging workmanship
6. Any component loose or otherwise not securely retained	
7. Any functioning part that works with difficulty	
8. Faulty workmanship or other irregularities	

4.5.2 Functional tests. Seats, in the quantities specified below, shall be subjected to the dynamic tests of 4.6.2.2:

(a) Two seat systems from each lot of 200, or fraction thereof, of each type, class, and size

(b) Three seat systems from each lot of 500, or fraction thereof above 500, of each type, class, and size

(c) One seat system from each additional lot of 500, or fraction thereof above 500 of each type, class, and size.

4.5.3 Lot. An inspection lot shall consist of seats manufactured under essentially the same conditions and from essentially the same materials and components.

4.6 Methods of examination and test.

4.6.1 Fit, Function, and Design conformance examination. Representative seats of the required type(s), class(es), and size(s) shall be furnished and installed in the applicable aircraft. The seats shall then be inspected for conformance to 3.3, 3.4, 3.5, 3.7, 3.9, 3.11, 3.12, 3.13, and 3.14. Occupants representing 5th and 95th percentile passengers or troops, as applicable with and without combat assault equipment, shall be used to demonstrate satisfactory restraint system use, seat accommodations, and lack of encumbrances during ingress and egress. Occupants shall wear warm-weather, intermediate-weather, and cold-weather clothing for each of the demonstrations. For troops, medium rucksacks and butt packs, with combat assault loads, shall be demonstrated. Ingress, hookup, and egress shall be timed for each combination of clothing, equipment, and personnel percentile. Times for seat installation, disconnect, folding, and stowage shall also be measured.

4.6.2 Structural tests. Each seat of the required type, class, and size shall be tested as a complete unit and shall be mounted in a suitable fixture by using the normal seat system to aircraft structure tiedowns. The fixture shall be representative of the aircraft's surrounding structure and spring rates. Additionally, for the static tests, attachments shall be distorted per 3.3.3.1 prior to load application. The seat shall then be subjected to, and satisfactorily withstand the loads specified in 4.6.2.1 and 4.6.2.2.

4.6.2.1 Static tests. The occupant restraint shall be tested with the rest of the seat during the static tests specified in Table 1. In addition, the lap belt and shoulder harness shall be statically tested separately to determine compliance with Table 2, thereby insuring that all components possess the required elongation and strength margin. The static test loads shall be applied where shown on Figure 14 through a body block which is contoured as shown. The body block shall include representations of the neck, the shoulders, and the upper legs.

The load shall be applied while the load-deformation performance of the seat is recorded. Deflection shall be measured from the seat pan (see Figures 11 and 12), and from the occupant CG for vertical. Total static test load to be applied, for all directions, shall be determined by multiplying the required design load factor (G) specified in Table 1 by the sum of the occupant and equipment weight plus the weight of the seat.

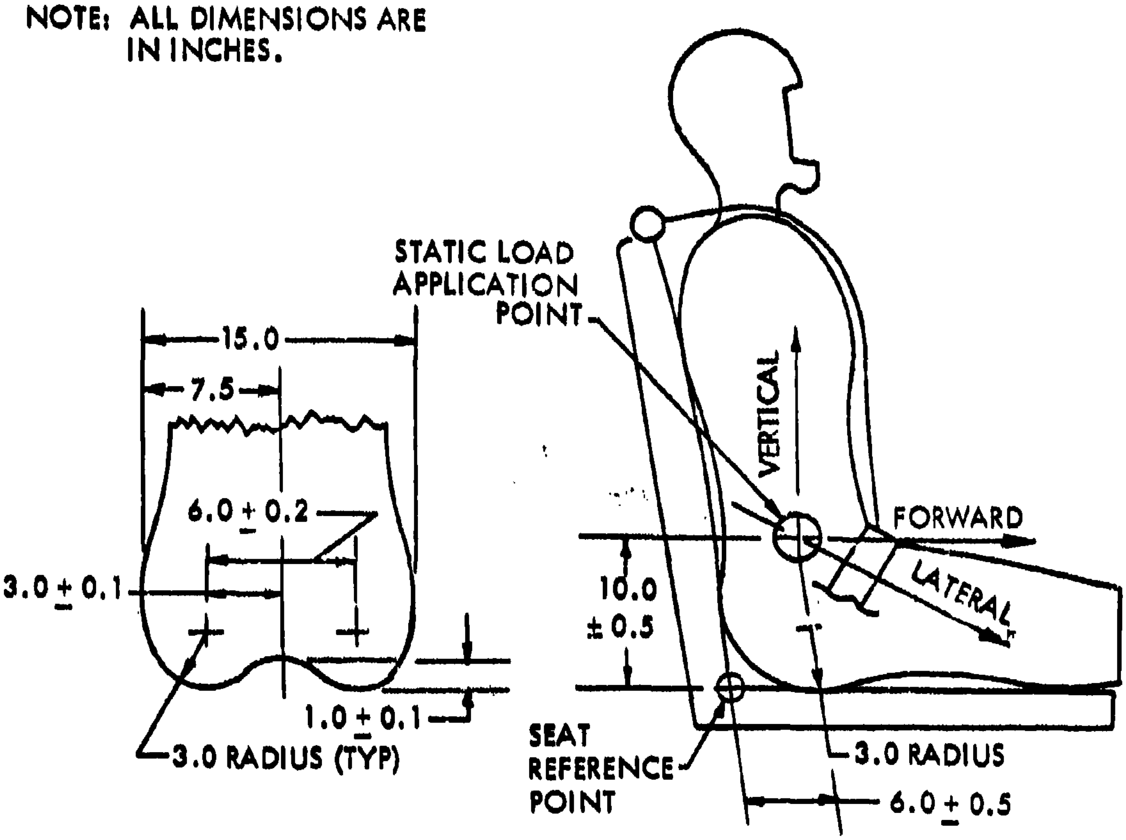


Figure 14. Static load application point and critical dummy pelvis geometry.

4.6.2.2 Dynamic tests. Dynamic first article tests of the seat shall be conducted to the conditions specified in Figure 3, and the seat shall evidence no loss of structural integrity. Dynamic sampling (quality conformance) tests of the seat shall be conducted in accordance with Test I only. The energy absorption mechanism shall limit the acceleration measured on the seat pan to a value which stays within the acceptable pulse duration of Figure 12. Excursions above the 15.5G plateau level for short durations not to exceed 10 milliseconds and accelerations not to exceed 10G are permissible as long as the ejection seat design limits in USAAMRDL TR 71-22 Eiband curve are not exceeded. A 95th percentile clothed and equipped anthropomorphic dummy occupant of 242 lbs shall be used to simulate seat occupant for Test 2 of Figure 3 and a 50th percentile clothed and equipped anthropomorphic dummy occupant of 197 lbs shall be used for Test 1 of Figure 3. The 50th percentile dummy shall be in accordance with NHTSA FMVSS-208 and Part 572.

4.6.3 Reliability tests. Components subject to motion, such as fold hinges and belt buckles shall be subjected to cycling tests to demonstrate conformance to 3.8.

4.6.4 Environmental tests. At least one seat shall be subjected to each of the following environmental tests in the order listed. Upon completion of environmental tests, the seat shall be examined for operational capability and subjected to and pass Test I of Figure 3. One additional energy attenuating device of each type used on the seat shall be environmentally tested and stroked after testing to verify functional force-deflection values.

4.6.4.1 High Temperature. High-temperature tests shall be conducted in accordance with Method 501, Procedures I and II of MIL-STD-810.

4.6.4.2 Low Temperature. Low-temperature tests shall be conducted in accordance with method 502 of MIL-STD-810. The test temperature shall be -65 degrees F.

4.6.4.3 Sunshine. Sunshine tests shall be conducted in accordance with Procedure 1 of Method 505 of MIL-STD-810.

4.6.4.4 Humidity. Humidity tests shall be conducted in accordance with Method 507 of MIL-STD-810.

4.6.4.5 Fungus. If any material utilized in the construction of the seat system is suspected to be a nutrient to fungi, the material shall be tested in accordance with Method 508 of MIL-STD-810.

4.6.4.6 Salt fog. Salt fog tests shall be conducted in accordance with Method 509 of MIL-STD-810.

4.6.4.7 Dust. The seat system shall be subjected to the dust test specified in MIL-STD-810.

4.6.4.8 Vibration. Vibration tests shall be conducted in accordance with Method 514, Procedure I (parts 1, 2, and 3), of MIL-STD-810.

4.6.4.9 Mud. All mechanical joints and energy attentuators shall be coated with mud and the seat must operate before and after it has dried.

5. PACKAGING

5.1 Preservation and packaging. Preservation and packaging shall be level A or C, as specified (see 6.2).

5.1.1 Level A. Each seat shall be preserved and packaged in accordance with MIL-P-116, Method III, in a weather-resistant container conforming to PPP-B-636.

5.1.2 Level C. Each seat shall be preserved and packaged in a manner that will afford adequate protection against corrosion, deterioration, and physical damage during shipment from the supply source to the first receiving activity for immediate use. This level may conform to the supplier's commercial practice, provided the latter meets the requirements of this level.

5.2 Packing. Packing shall be level A, B, or C, as specified (see 6.2).

5.2.1 Level A. Seats preserved and packaged as specified in 5.1.1 shall be packed in overseas-type shipping containers conforming to PP-B-601 or PPP-B-621. As far as practicable, shipping containers shall be of uniform shape, size, and minimum cube and tare consistent with the protection required, and contain identical quantities. The gross weight of each shipping container shall not exceed the weight limitation of the specification. Containers shall be closed and strapped in accordance with the above specifications and appendicies thereto.

5.2.2 Level B. Seats preserved and packaged as specified in 5.1.1 shall not be overboxed for domestic shipments. The container, closed and strapped in accordance with the applicable appendix of the container specification, shall be the shipping container.

5.2.3 Level C. Seats shall be packed in a manner that will afford adequate protection at the lowest rate against damage during direct domestic shipment from the supply source to the first receiving activity and are destined for immediate use at that activity. This level shall conform to applicable carrier rules and regulations and may be the supplier's commercial practice, provided the latter meets the requirements of this level.

5.3 Physical protection. Cushioning, blocking, and bracing shall be in accordance with MIL-STD-1186, except for domestic shipments. Waterproofing requirements for cushioning materials and containers shall be waived when preservation, packaging, and packing designed for immediate use of the item, or when drop tests of MIL-P-116 are applicable.

5.4 Marking. Interior packages and exterior shipping containers shall be marked in accordance with MIL-STD-129.

6. NOTES

6.1 Intended use. The seats covered by this specification are intended for use by troops and passengers in helicopters, and to provide crash survival for most of these occupants in the majority of crashes.

6.2 Ordering data. Procurement documents should specify the following:

(a) Title, number, and date of this specification.

(b) Type, class, and size of seat required (see 1.2).

6.3 Definitions. For the purpose of this specification, the following definitions apply.

6.3.1 Anthropometric data. U.S. Army Natick Labs Report 72-51-CE shall be referred to as a source document for anthorpometric data on troops/passengers.

6.3.2 Occupant weights and equipment. Unless otherwise specified, the occupant and equipment weights in Table 4 are applicable for design and test considerations.

TABLE 4. OCCUPANT WEIGHTS			
Item	95th Percentile wt-lb	50th Percentile wt-lb	5th Percentile wt-lb
Troop Weight	201.9	156.3	126.3
Clothing (Less Boots)	3.0	3.0	3.0
Boots	4.0	4.0	4.0
Equipment	33.3	33.3	33.3
Total Weight	242.2	196.6	166.6
Vertical Effective Weight Clothed	163.9	127.4	103.4
Vertical Effective Weight Equipped	197.2	160.7	136.7

6.3.3 Effective weight of occupant. The effective weight of a seated occupant in the vertical direction is the sum of the following quantities: 80 percent of the occupant's body weight, 80 percent of the weight of the occupant's clothing less boots, and 100 percent of the weight of any equipment carried totally on the oc upant's body above knee level.

6.3.4 G. The term G is the ratio of a particular acceleration to the acceleration due to gravitational attraction at sea level; therefore, 10G represents an acceleration of 321.7 feet/second/second.

6.3.5 Occupant submarining. In a crash with high vertical and longitudinal forces (measured along the seat longitudinal axis) present, the restrained body will tend to sink down into the seat first and then almost simultaneously be forced forward. If the seat is provided with an improperly designed restraint or seat cushion, the inertia load of the hips and thighs will pull the lower torso under the lapbelt during the crash sequence. This phenomenon is referred to as occupant submarining.

6.3.6 Dynamic overshoot. Dynamic overshoot exists when the seated occupant receives an amplification of the accelerative force applied to the seat. A loose or highly elastic system, or highly elastic cushion, can facilitate dynamic overshoot.

CRASH SURVIVAL DESIGN GUIDE CHANGE RECOMMENDATIONS

Modifications were recommended to USAAMRDL TR 71-22, "Crash Survival Design Guide". The affected paragraphs of TR 71-22 have been reproduced, and the recommended changes are noted by crosshatching (////) portions deleted and underlining (____) portions added.

3.3.2.1 The same percentile range of occupant sizes should be considered for troop seat design. ~~Since more flexibility is available in the design of troop seats, the typically large clothing and equipment variations for troops should be considered.~~ Since a greater range of clothing and equipment is used by troops than by aviators, troop seats should be designed to accommodate these variations. The 95th percentile occupant should be considered heavily clothed and equipped, while the 5th percentile occupant should be considered lightly clothed and equipped. ~~Based on data contained in References 22 and 23.~~ It is not reasonable, however, to design a crashworthy troop seat to accommodate the full range of equipment which can be carried by troops. A subsistence load weighs over 90 pounds and would be carried in a large rucksack with a Lincloe carrying frame. The depth of such equipment is 17 inches and cannot be accommodated within a reasonable seat depth. Such equipment will be removed and placed on the floor. Seat design should be limited to accommodations for the size and weight range of troops without equipment, and to troops with combat assault equipment. The typical weights of seated troops in aircraft per Natick Labs report 72-51-CE and USAAMRDL TR-74-93 are: (1)

	95th Percentile (lb)	
Man	~~192.0~~	201.9
Clothing	~~3.2~~	3.0
Boots	4.0	
~~Protective Vest~~	~~8.5~~	
Helmet with Liner	3.0	
~~Equipment~~	~~27.3~~	
~~Field Pack with Sleeping Bag~~ Combat Assault Pack and Equipment Not Including Rifle	~~17.2~~	33.3
	~~255.2~~	245.2

(2)

	5th Percentile (lb)	
Man	~~124.0~~	126.3
Clothing	~~2.0~~	3.0
Boots	4.0	
Helmet	3.0	
	~~133.0~~	136.3

(Revise Figure 3.23)
Revise the force deflection curve of Figure 3.23B creating new figure which agrees with Figure 11 of the draft Military Specification Seat, Helicopter, Troop and increase the stroking distance from 6 to 12 inches. 3

3.3.4 LATERAL STRENGTH AND DEFORMATION REQUIREMENTS

The lateral load and deformation requirements for forward- and aft-facing seats are presented in Figure 3-24 for the 95th percentile accident (see Table 1-II in Chapter 1). Two curves are presented. One is for rotary-wing aircraft and the cockpits of large fixed-wing aircraft. The other is for light fixed-wing aircraft and cabins of large fixed-wing aircraft. The deflections are to be measured at the neutral seat reference point. Occupant weight should be as stated in paragraph 3.3.1. Controlled deformation for side-facing seats shall be increased from the 4 inches shown to 8 inches. 4 4

(Revise Figure 3-24)
Revise Figure 3-24 to make two figures, one for crew seats and one for troop/passenger seats. Revise the force deflection curve for troop/passenger seats to agree with Figure 2 of the draft Troop Seat Military Specification and increase the stroking distance from 4 to 6 inches. 5

3.5.2 SEAT COMPONENT ATTACHMENT

Since components that break free during a crash can become lethal weapons, it is recommended that attachment strengths be consistent with those specified for ancillary equipment. Static attachment strengths for components, e.g., armored panels, should therefore be as follows:

Downward:	35G
Upward:	15G
Forward:	35G

Aftward: 15G

Lateral: 20G

These criteria may be somewhat conservative for load-limited seats. However, load limiting is mandatory in the vertical (6) direction only. ~~In light of the potential hazard, the strength requirements are felt to be justified.~~ Therefore, these loads shall apply only to the seats in the directions that have no load-limiting provisions.

RATIONALE FOR CHANGES TO USAAMRDL TR 71-22

1. To limit the range of equipment for which troop seats should be designed. The large rucksack with Lincloe frame is 17 inches deep, which is excessive for the seat depth limitations and cabin space specified by the using agencies.

2. The weight of the 95th percentile troop has increased 9.9 pounds, per Natick Labs Report 72-51-CE. Troop equipment weight for combat assault operations is reduced 20 pounds, which included the weight of the sleeping bag and protective vest (not used on combat assault operations) and the M-16 rifle, which is not effective on seat load.

3. The force deflection curve, for troop/passenger seats in Figure 3-23 is not attainable because of the flexibility of these seats. Increased deformation should be permitted because these seats do not have the control column and instrument panel clearance restrictions that crew seats have.

4. The lateral deformation curve, Figure 3-24, is not applicable to side-facing seats due to lower lateral human tolerance.

5. The force deflection curve for troop/passenger seats in Figure 3.24 is not attainable because of the flexibility of these seats.

6. Design for loads considerably above the load-limited loads on lightwaight troop seats imposes a severe weight penalty.

7. Vertical static load requirements considerably above the load-limited load on all seats are unnecessarily costly in weight if the seat bottoms out on the floor before the energy attenuator bottoms.

8. Seats not subject to vertical binding due to horizontal distortion should not be subjected to any unnecessary test.

TABLE 3-II. SEAT DESIGN AND STATIC TEST REQUIREMENTS

Test Ref No.	Loading Direction With Respect to Fuselage Floor	Load Required	Deformation Requirements[a]
1	Forward	See Figure 3-23	See Figure 3-23
2	Aftward	12G Minimum	No Requirement
3	Lateral[b]	See Figure 3-24	See Figure 3-24
4	Downward/		
	Crew Seat	$14.5 \pm 1.0G$[d,e]	See Paragraph 3.3.3.1
	Troop Seat	$14.5 \pm 1.0G$[d]	
5	Upward	8G Minimum	No Requirement
6	Forward[c,f]	See Figure 3-23[c]	See Figure 3-23
Combined	Downward/		
	Crew Seat	$14.5 \pm 2.0G$	
	Troop Seat	$14.5 \pm 2.0G$	Same as Test 4
	Lateral[f]	9G Minimum	No Requirements

[a]The aircraft floor or sidewall should be deformed in the xz and yz planes, as detailed in paragraph 3.2.4.4 and in Figure 3-27, simultaneously with the G loads specified.

[b]The lateral loads should be applied in the direction which is most critical. In the case of symmetrical seats, the loading direction is optional.

[c]In the event that no load-limiting device is used in the forward direction, a 20G load for cabin seats and a 25G load for crew seats may be used for this combined loading.

[d]If more than one load-limiter setting is provided, each should be tested.

[e]Subsequent to the stroking of the vertical energy-absorbing device, the seat should carry a vertical static load of 25G, based on the effective weight of the 95th percentile occupant plus seat and equipment, without loss of attachment to the basic structure/ ~~except when the seat pan is resting on the floor.~~ Plastic deformation is acceptable in this test. 7

[f]The forward and lateral loads should be applied prior to the downward load application/ ~~on seats employing vertical slide tubes or guides which could distort and cause binding.~~ 8

APPENDIX A

CRASHWORTHY TROOP SEAT TESTING COMPONENT TEST PLAN

1. INTRODUCTION

The crashworthy troop seat test program includes component tests, static tests, and dynamic tests. This test plan covers the testing of seat components which can be static tested separately from the basic seat structure. Tests will be conducted in the Instron tensile testing machine which has a capacity of 10,000 lb. The machine produces a printout of load versus deflection.

Four component test set-ups will be made. Three of the set-ups will test a number of components in series with energy attenuators. The load, therefore, will be limited to the stroking load of the attenuators. Determination of excessive deformation of components or their failure before reaching the stroking load will be the principal purpose of the test. Verification of the attenuators' stroking load will also be accomplished. The fourth test setup will not include an energy attenuator and therefore will not be load limited. The floor attachment quick disconnect, which will be one of the components in the setup, will be tested to destruction.

2. STATEMENT OF WORK

Perform tensile load testing on crashworthy troop seat components as follows:

> Test 1 - In this test, the wire-bending energy attenuator used for vertical impact load limiting will be tested. Also in series with the attenuator are the turnbuckle for coarse seat adjustment and the overcenter toggle latch for final seat adjustment, tensioning, and locking. These series of components will be installed in the Instron test machine by the use of adaptor plates (Figure A-1). The load will be applied in increments of 300 lb, with the machine being stopped after each increment and any deformation noted. Loads will be increased until the energy attenuator begins stroking. The stroking will be allowed to continue until the limit of the attenuator length or machine pull distance limit is reached.

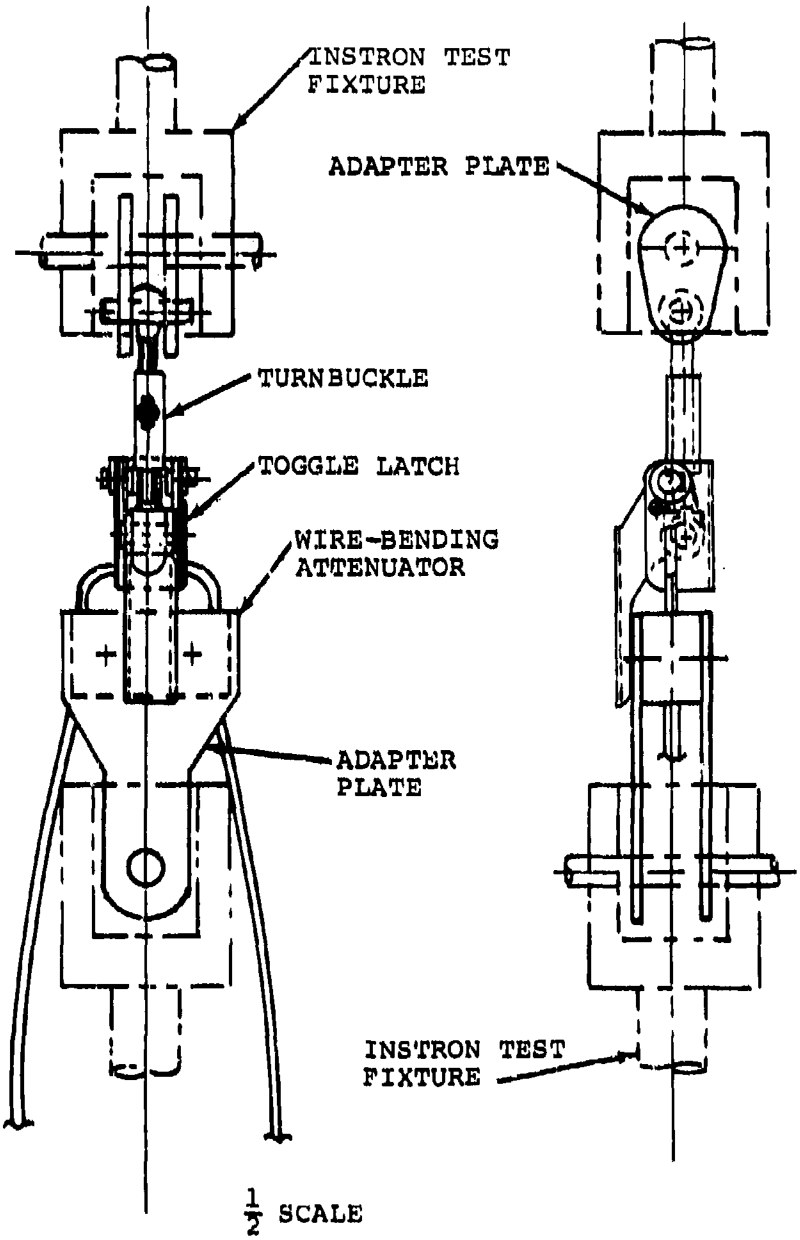


Figure A-1. Vertical energy attenuator and toggle latch test specimen.

Test 2 - The lateral energy-attenuator cable and front floor quick-disconnect fitting and stud will be the specimens of this test. The floor attachment stud and pan fitting will be mounted in the Instron tensile tester at an angle to simulate the normal relationship of the cable with the floor (Figure A-2). Adapters attach the test specimen to the machine. Loads will be applied in increments of 300 lb, with the machine being stopped at each increment and any deformation noted. Loads will be increased until the energy attenuator begins stroking. The stroking will be allowed to continue until the ultimate of the attenuator or the machine pull distance limit is reached.

Test 3 - The longitudinal energy attenuator (E/A) and back floor quick-disconnect fitting and stud will be the specimens of this test. The floor attachment stud and pan fitting will be mounted in the Instron tensile tester at an angle to simulate the normal angle of the attenuator strut with the floor (Figure A-3). Adapters attach the test specimen to the machine. Loads will be applied in increments of 300 lb, with the machine being stopped at each increment and any deformation noted. Loads will be increased until the E/A strut begins stroking. The stroking will be allowed to continue until the limit of the E/A length or the machine pull distance limit is reached.

Test 4 - The vertical holddown cable and back floor quick-disconnect fitting and stud will be the specimens of this test. Although the quick disconnect fitting is subject to test in Test No. 3, that test applies a predominant shear load on the floor stud. Test No. 4 applies a tension load on the stud and the loads will not be limited by an energy attenuator. The holddown cable is of high-strength low-elongation material, and minimum elongation or stroking will be experienced. The test specimen will be mounted in the Instron test machine in a manner similar to Tests 2 and 3 (Figure A-4). Loads will be applied in increments of 300 lb, with the machine being stopped at each increment and any deformation noted. Loads will be increased until failure occurs.

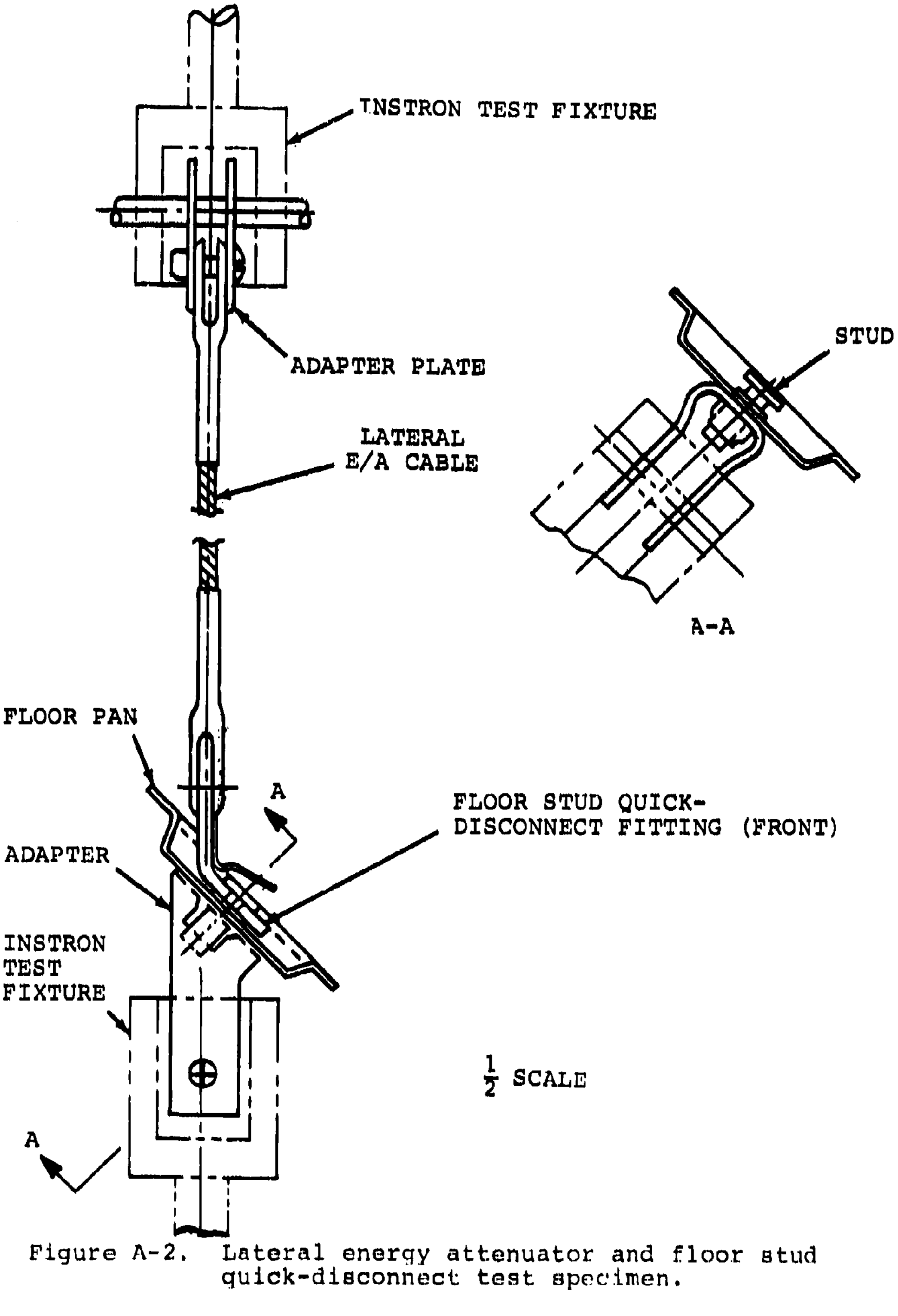


Figure A-2. Lateral energy attenuator and floor stud quick-disconnect test specimen.

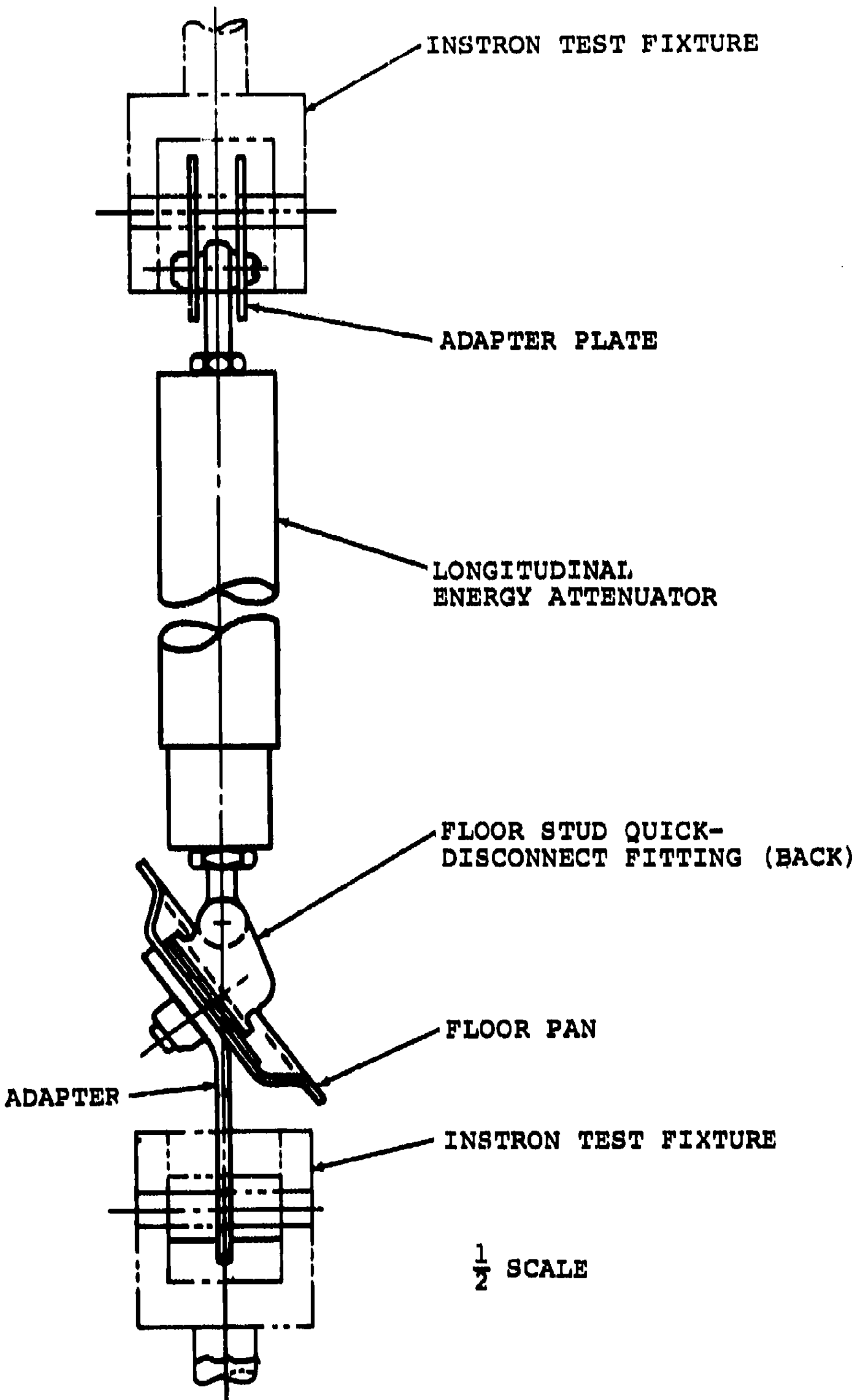


Figure A-?. Longitudinal energy attenuator and floor stud quick-disconnect test specimen.

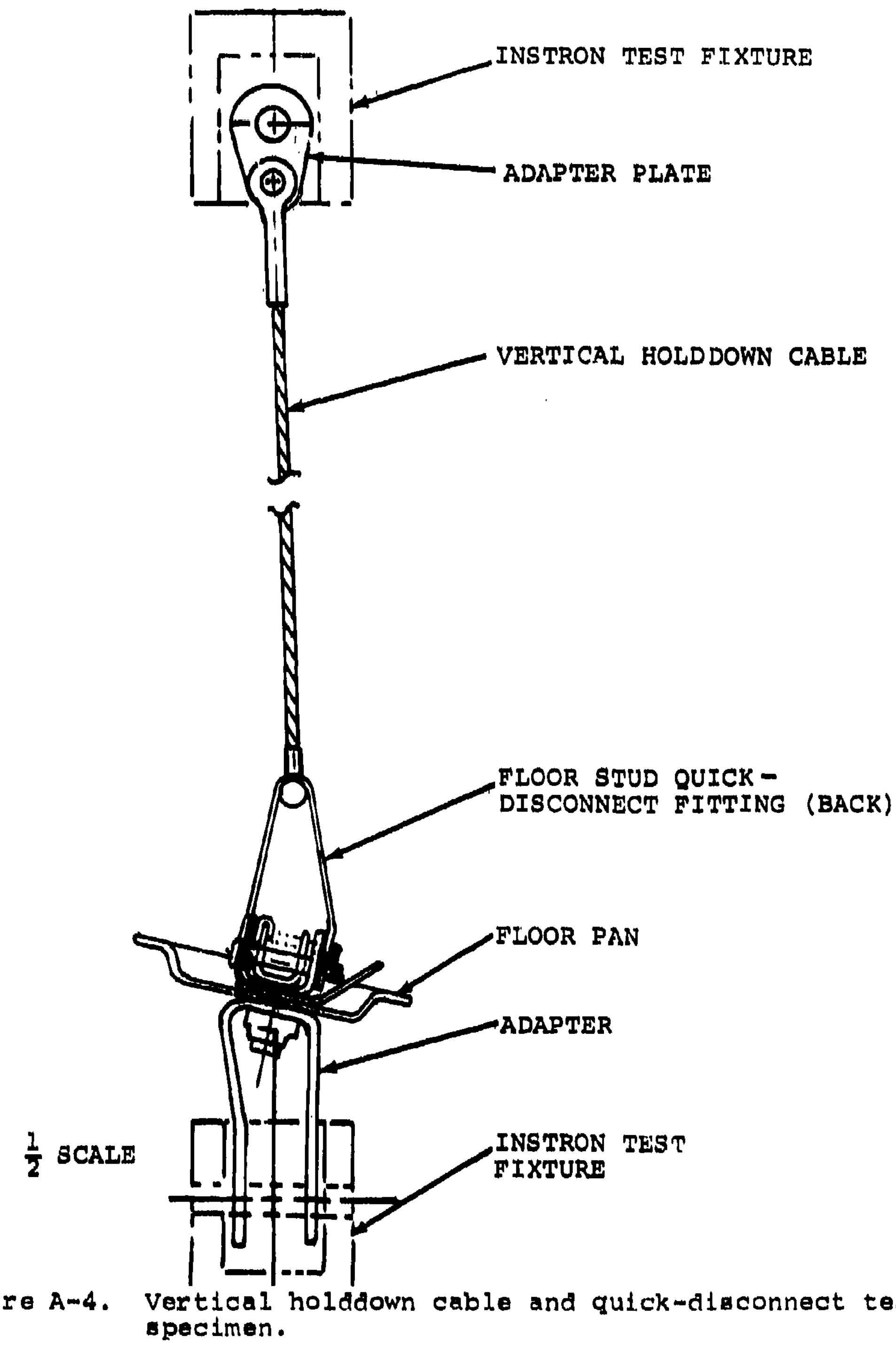


Figure A-4. Vertical holddown cable and quick-disconnect test specimen.

Test Record - A force deflection curve printout will be produced for each of the four tests. The machine speed will be set at 10 in. per minute and the paper speed set at 10 in. per minute. Still photographs will be made for each specimen in the machine before and after testing. Failed parts will be disassembled and photographed.

APPENDIX B

STATIC TEST PLAN

CRASHWORTHY TROOP SEAT

INTRODUCTION

Contract DAAJ02-74-C-0036 has been awarded to The Boeing Company to design, build and test forward- and aft-facing crashworthy troop seats. Component tests, static tests and dynamic tests will be performed. This document sets forth a test plan to static-test the troop seats under simulated crash loads and to determine energy attenuator function and seat integrity. Five static test setups will be made, two for the forward-facing seat and three for the aft-facing seat.

STATEMENT OF WORK

Static test of the crashworthy troop seats shall consist of the following tasks:

1. Design and fabrication of a test fixture
2. Seat installation
3. Loading and instrumentation
4. Static testing
5. Photographic coverage
6. Data of instrumentation recordings

TEST FIXTURE DESIGN AND FABRICATION

A test fixture shall be designed and fabricated which will support the test specimens in the same geometric manner as it would be in the aircraft (Figure B-1). The fixture shall be capable of supporting the seat, without deflecting, while loads are applied as specified in the test section. Floor-connection pans and ceiling-attachment brackets shall be bolted to the test fixture so that seat quick-disconnect fittings can be used to rapidly install or remove the seat from the fixture. The floor-attachment pans shall be installed in a manner so that floor warpage can be demonstrated (Figure B-2). The ceiling bracket shall be pin-jointed to permit lateral rotation (Figure B-3).

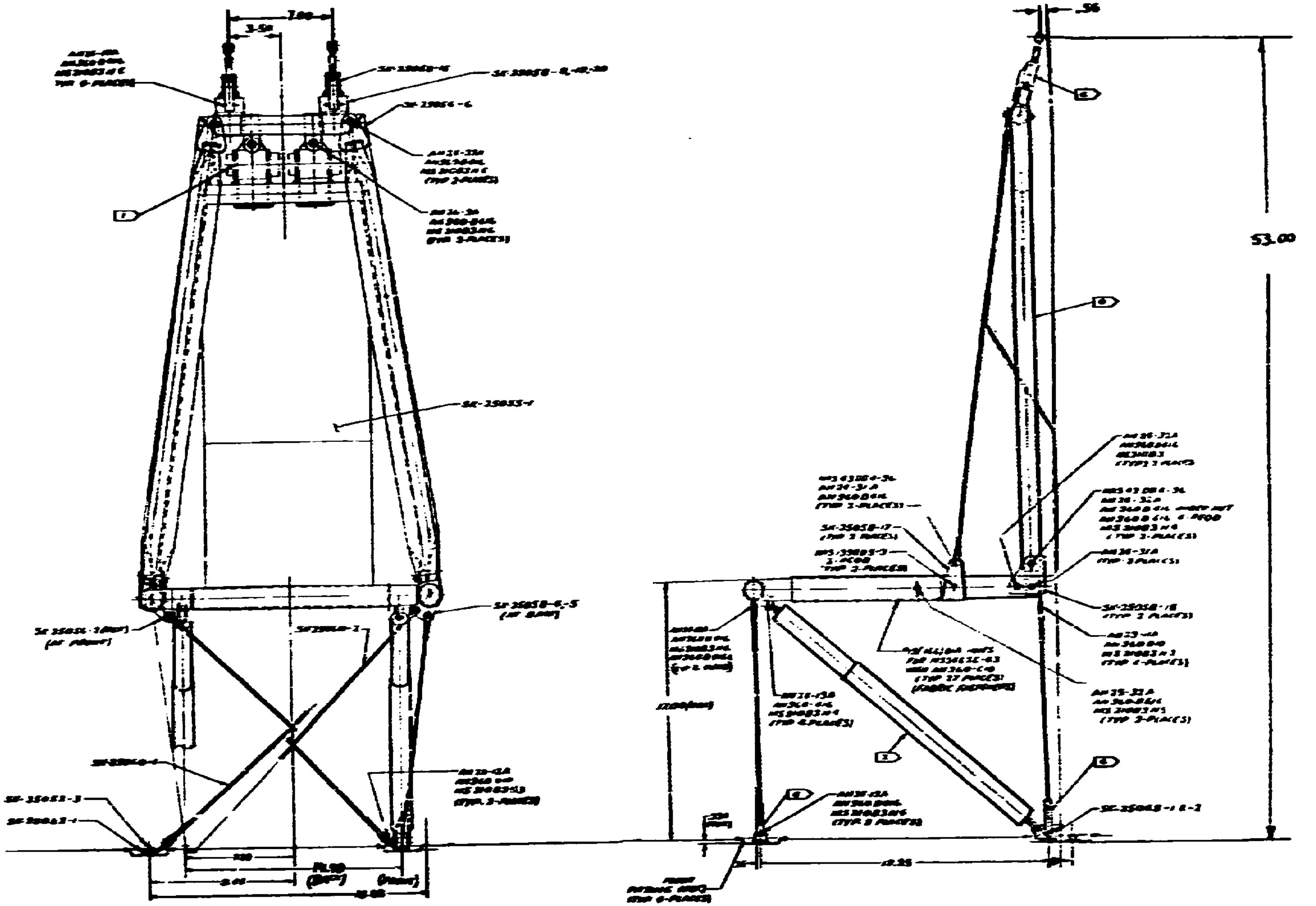
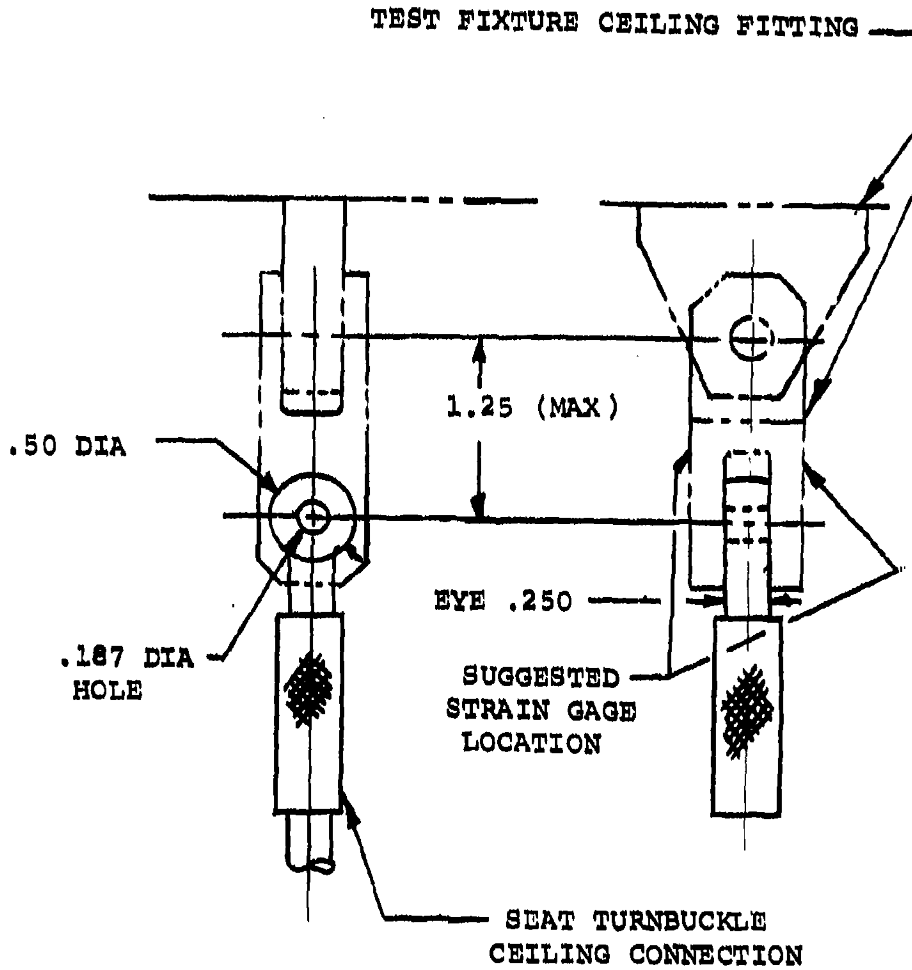


Figure B-1 . Seat installation.



Note: Dimensions are in inches

Figure B-2. Ceiling connection fitting.

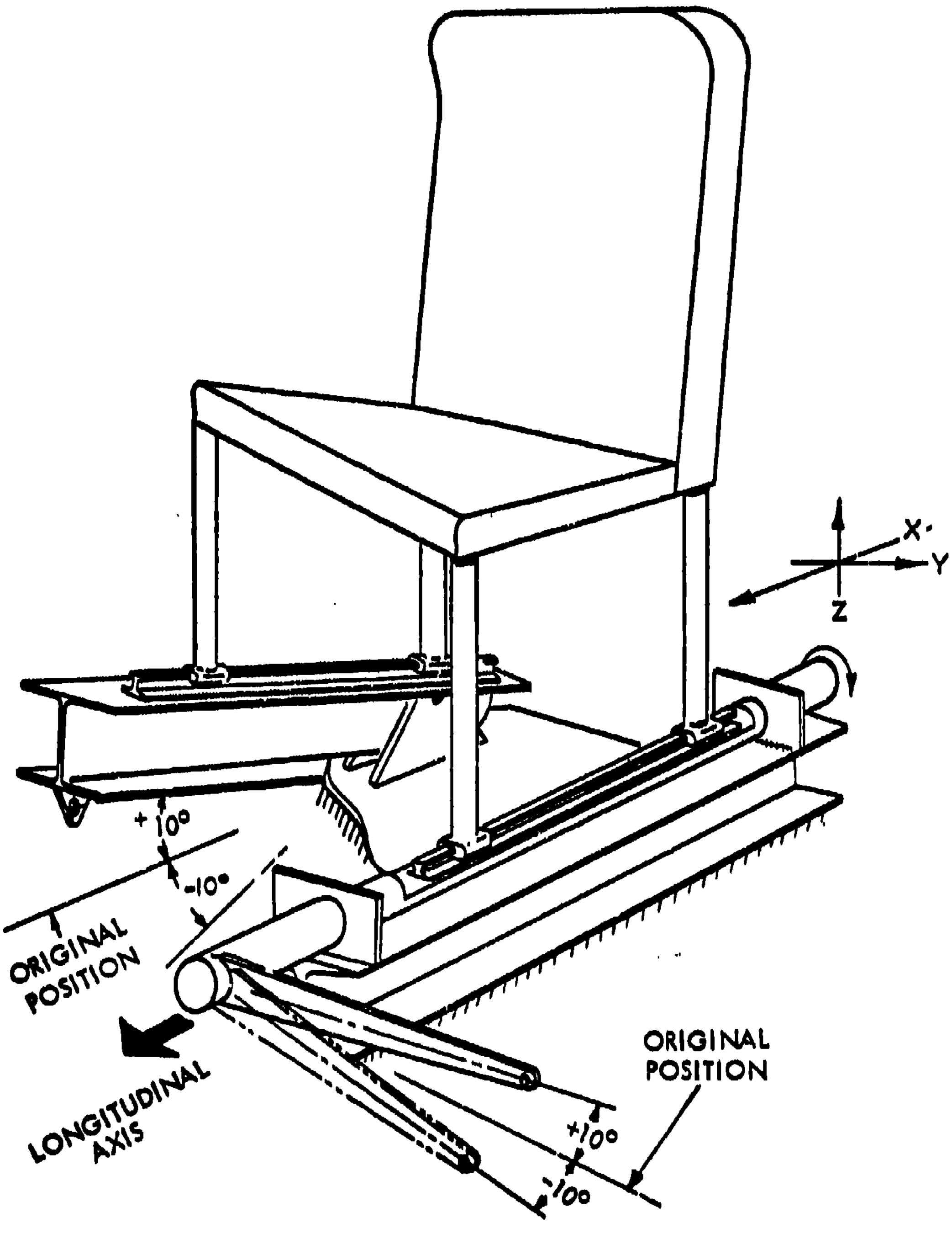


Figure B-3. Floor warpage requirement.

The test fixture shall be designed to permit a minimum seat displacement of 12 in. laterally and 24 in. frontward or backward without contacting the fixture.

The same test fixture shall be adaptable for the five test conditions. A minimum preparation shall be required to convert the fixture from one test condition to another.

SEAT INSTALLATION

The seat shall be installed in the test fixture as in the aircraft (Figure B-1). The floor fittings and ceiling-connection locations are interchangeable for forward- or aft-facing seats. The procedure for seat installation is as follows:

1. Attach turnbuckles at top of seat to ceiling brackets.
2. Release toggle latches at turnbuckles.
3. Attach quick-disconnect fittings at front of seat to floor studs.
4. Attach quick-disconnect fittings at back of seat to floor studs.
5. Close toggle latches at ceiling.
6. If seat is out of adjustment, open toggle latches, adjust turnbuckles, and close toggle latches.
7. Install safety pin through toggle latch.

LOADING AND INSTRUMENTATION

The specified load shall be applied to the body block at one point. Load direction specified shall not vary more than ± 5 degrees as the seat strokes. A load cell shall be provided in the load applicator, and the output shall be capable of being used to produce a curve showing force in pounds versus deflection in inches. Instrumentation shall be installed on the seat in the following locations:

1. Strain gages on the ceiling connection fittings of the test fixture (two places)(Figure B-3).
2. Tensiometer attached to one lapbelt strap.
3. Tensiometer attached to both shoulder straps.
4. Strain gage attached to the eyebolt at the end of the diagonal-strut energy attenuator (two places).
5. Strain gages attached to the front and back diagonal cable fork fittings (load-carrying cable on combined and side-loading test only).
6. Load cell attached to each side of seat at lapbelt attachment fittings and lapbelt attached to load cells.

This instrumentation shall produce a force output in pounds which can be plotted versus deflection in inches. Strain-gaged seat components shall not be reused for subsequent tests.

STATIC TESTING

Five static tests shall be performed using a Government-furnished body block. Prior to the load application in each test the floor warpage provisions shall be operated to the extent shown in Figure B-2, and shall remain in this position for the test. Each static test shall be performed as follows, using a new seat:

<u>Test 1 - Forward-Facing Seat, Forward Loading</u>

A load shall be applied at the center of gravity of the body block, in a forward direction and parallel to the floor. Loading shall be applied in a continuous manner. The seat shall be photographed from a fixed position at increments during the deformation. Some stroking of the ceiling attenuators at low loads is anticipated due to the bowstring effect. As the angle of the attenuator with the ceiling decreases, the stroking will decrease until a stable position is reached and the lower, diagonal attenuators under the seat pan begin stroking. When the lower attenuators begin stroking, loading is to be continued until the seat pan has moved 10 in. in a forward direction. Applied load is approximately 3870 lb minimum force, which is 15 G multiplied by 258 lb, the 95th percentile fully-equipped troop weight plus seat weight. Force versus deflection shall be recorded during seat stroking.

<u>Test 2 - Forward-Facing Seat, Three-Axis Loading</u>

The resultant of the three-axis loading shall be applied to the body block at the center of gravity. The angle of the resultant load shall be determined by using the following load vectors:

14.5	G Downward	X	177*	=	2567 lb
15	G Forward	X	258**	=	3870 lb
9	G Lateral	X	258**	=	2322 lb

---

* 50th percentile fully equipped troop effective vertical weight plus 14 lb effective seat weight.

**95th percentile fully equipped troop weight plus 14 lb effective seat weight.

Loading shall be applied in a continuous manner. The seat shall be photographed from a fixed position at increments during deformation. When the loading reaches 5000 lb (the approximate resultant load), loading is to be continued until the seat has stroked 10 in. in the forward direction or has contacted the floor. Force versus deflection shall be recorded during seat stroking.

Test 3 - Aft-Facing Seat, Three-Axis Loading

The resultant of the three-axis loading shall be applied to the body block at the center of gravity. The angle of the resultant load shall be determined by using the following load vectors:

14.5 G	Downward	X	177	=	2567 lb
15 G	Rearward	X	258	=	3870 lb
9 G	Lateral	X	258	=	2322 lb

The same conditions applying to Test 2 shall apply to this test. This test shall be given the lowest priority, due to its similarity to Test 2, and shall be deleted in the event of failure during Test 1 or Test 2. If failure occurs in Test 1 or Test 2, the seat designated for Test 3 shall be modified as necessary and a retest of Test 1 or Test 2 shall be performed.

Test 4 - Aft-Facing Seat, Rearward Loading

A load shall be applied at the center of gravity of the body block, in a rearward direction of the seat and parallel to the floor. Loading shall be applied in a continuous manner. The seat shall be photographed from a fixed position at increments during deformation. Some stroking of the ceiling attenuators at low loads is anticipated due to the bowstring effect. As the angle of the attenuator with the ceiling decreases, the stroking will decrease until a stable position is reached and the lower, diagonal attenuators under the seat pan begin stroking. When the lower attenuators begin stroking, loading is to be continued until the seat pan has moved 10 in. in a rearward direction. Minimum load is approximately 3870 lb, which is 15 G multiplied by 258 lb, the 95th percentile fully equipped troop weight plus seat weight. Force versus deflection shall be recorded during seat stroking.

Test 5 - Aft-Facing Seat, Lateral Loading

A load shall be applied at the center of gravity of the body block, in a lateral direction and parallel to the floor. Loading shall be applied in a continuous manner. The seat shall be photographed from a fixed position at increments during the deformation. It is anticipated that the ceiling attenuators will stroke first due to the bowstring effect. Stability is reached as the angle of the attenuator with the ceiling decreases. When the lower attenuators begin stroking, loading is to be continued until the seat pan has moved laterally 6 in. Minimum load is approximately 2580 lb, which is 10 G multiplied by 258 lb, the 95th percentile fully equipped troop weight plus seat weight. Force versus deflection shall be recorded during seat stroking.

PHOTOGRAPHIC COVERAGE

Photographs shall be taken before and after each test. Five pre-test photographs shall be taken showing the complete seat in the test fixture. The photographs shall include a frontal, side, rear, and three-quarter view, and a view showing the load applicator attachment to the body block. A minimum of four post-test photographs shall be taken and shall include front, rear, side, and three-quarter view. Additional photographs shall be taken as necessary to show failed components or excessive deformation. Photographs during deformation shall be taken as appropriate.

DATA

The data output of all instrumentation used shall be provided. The data shall be in the form of graphs showing force versus deflection. Deflection shall be measured from the seat pan.

APPENDIX C

DYNAMIC TEST PLAN

CRASHWORTHY TROOP SEAT

INTRODUCTION

Contract DAAJ02-74-C-0036 has been awarded to The Boeing Company to design, build, and test forward- and aft-facing crashworthy troop seats. Component tests, static tests, and dynamic tests will be performed. This document sets forth a test plan to dynamic-test the troop seats under crash impact conditions to determine energy attenuation and seat integrity. Four dynamic test setups will be made, two for the forward-facing seat, and two for the aft-facing seat.

STATEMENT OF WORK

Dynamic testing of the crashworthy troop seats shall consist of the following tasks:

1. Design and fabrication of a dynamic test fixture
2. Seat installation
3. Loading and instrumentation
4. Dynamic testing
5. Photographic coverage
6. Instrumentation data acquisition

TEST FIXTURE DESIGN AND FABRICATION

A test fixture shall be designed and fabricated which will support the test specimens in the same geometric manner as it would be in the aircraft (Figure C-1). The fixture shall be capable of supporting the seat, without deforming during dynamic load application as specified in the test section. Floor-connection pans and ceiling-attachment brackets shall be bolted to the test fixture so that seat quick-disconnect fittings can be used to rapidly install or remove the seat from the fixture. The ceiling bracket shall be pin-jointed to permit lateral rotation (Figure C-2).

The test fixture shall be designed to permit a minimum seat displacement of 12 in. laterally and 24 in. frontward or backward without contacting the fixture. Adequate clearance for dummy limb flailing shall be provided.

It is desirable that the same test fixture be adaptable for the four test conditions. A minimum preparation shall be required to convert the fixture from one test condition to another.

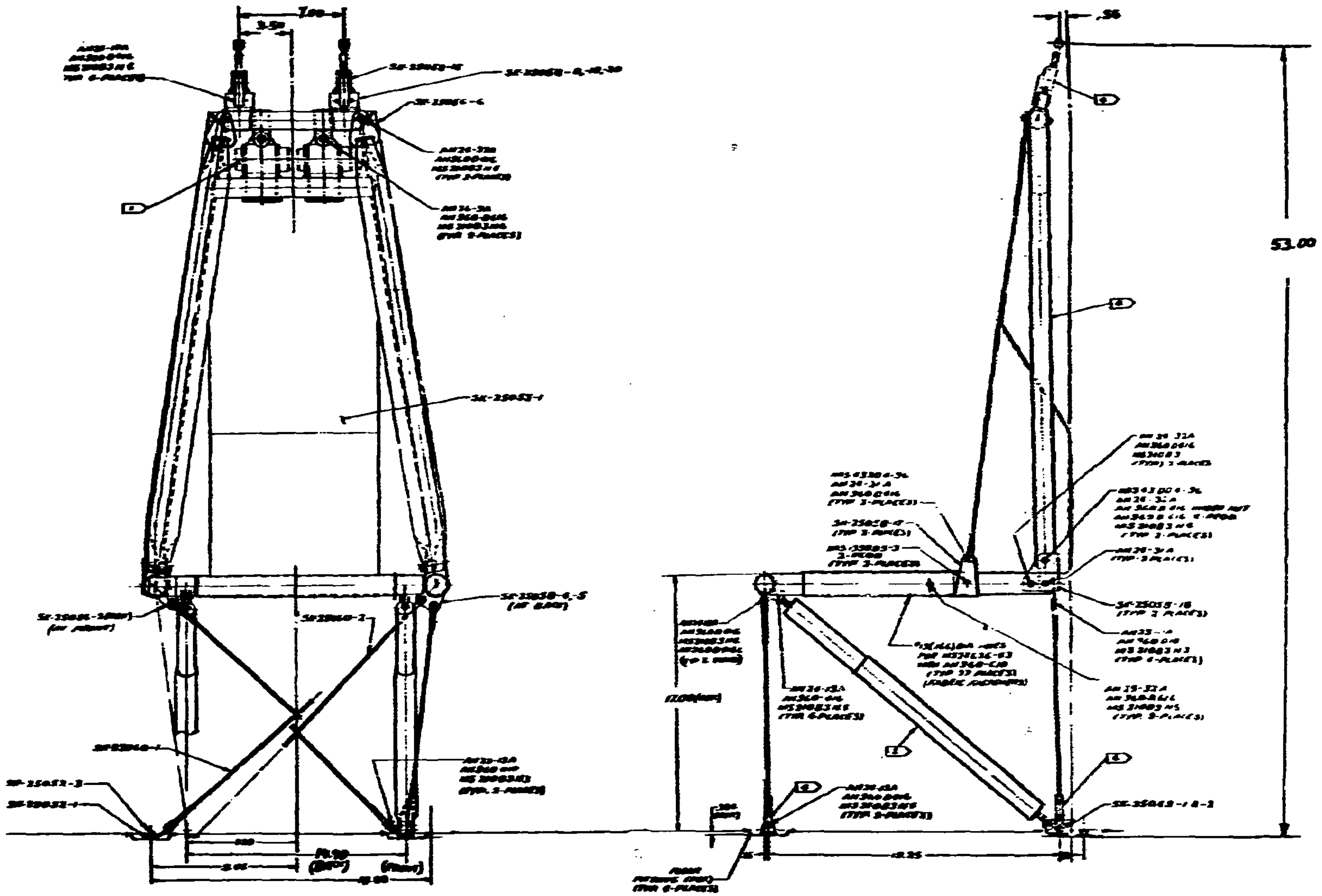
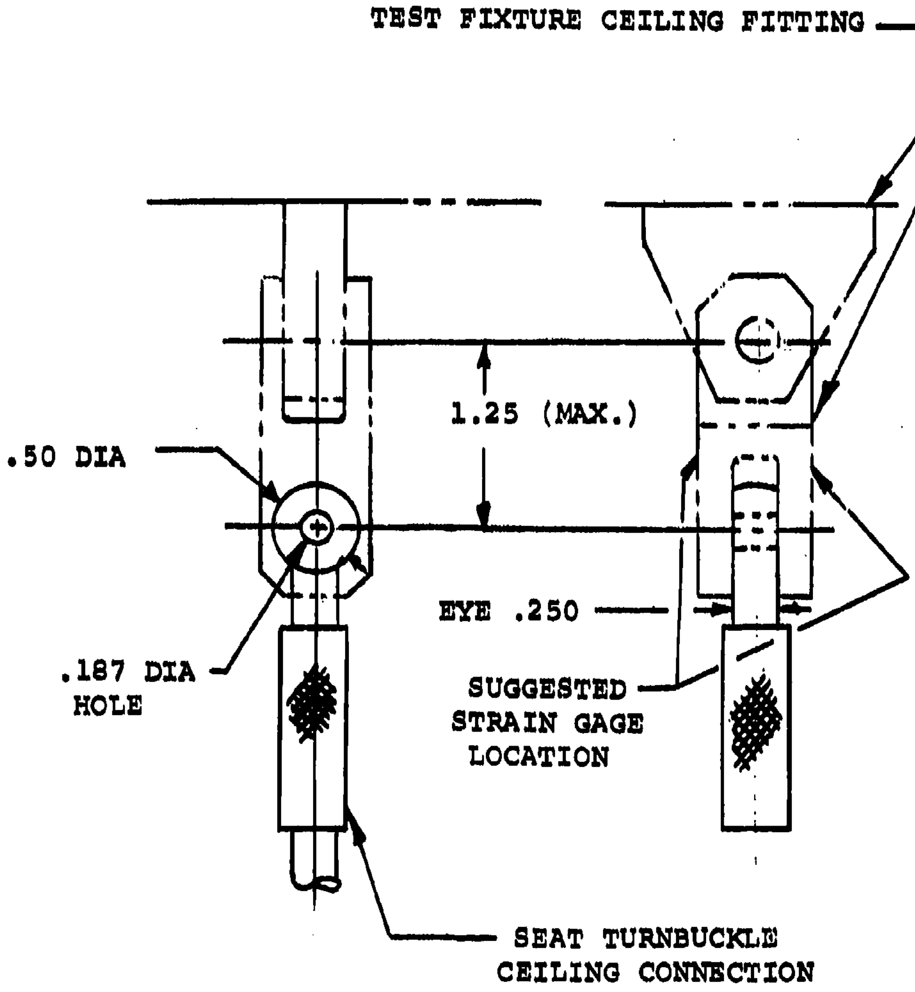


Figure C-1. Seat installation.



Note: Dimensions are in inches.

Figure C-2. Ceiling connection fitting.

SEAT INSTALLATION

The seat shall be installed in the test fixture as in the aircraft (Figure C-1). The floor fittings and ceiling connection locations are interchangeable for forward- or aft-facing seats. The procedure for seat installation is as follows:

1. Attach turnbuckles at top of seat to ceiling brackets.
2. Release toggle latches at turnbuckles.
3. Attach quick-disconnect fittings at front of seat to floor studs.
4. Attach quick-disconnect fittings at back of seat to floor studs.
5. Close toggle latches at ceiling.
6. If seat is out of adjustment, open toggle latches, adjust turnbuckles, and close toggle latches.
7. Install safety pin through toggle latch.

LOADING AND INSTRUMENTATION

Each seat shall be loaded with a 95th percentile anthropomorphic dummy weighted to a total weight of 209 lb, including clothing and boots. The dummy shall be wearing a combat assault pack and equipment (supplied by Boeing) which will weigh a total of 29.8 lb.

The dummy shall be instrumented with a three-axis accelerometer. Strain gages shall be placed on test components and the test fixture as specified for each test condition, the output of which shall show force in lb versus time. The accelerometer output shall show acceleration (G) versus time. Instrumentation shall be installed in the following locations for all tests except as noted:

1. Strain gages on the ceiling connection fittings of the test fixture, two places (Figure C-2).
2. Tensiometer attached to one lapbelt strap (Tests 1 and 2).
3. Tensiometer attached to both shoulder straps (Tests 1 and 2).
4. Strain gage attached to the eye bolt at the end of the diagonal-strut energy attenuator, two places (Tests 1 and 3).
5. Strain gages attached to the front and back diagonal cable fork fittings (load carrying cable) (Tests 2 and 4).
6. Accelerometer (three-axis) attached to the test fixture at floor level (two required).
7. Accelerometer (three-axis) in chest cavity of dummy.

DYNAMIC TESTING

Four dynamic tests shall be performed using anthropomorphic dummies with equipment. Each dynamic test shall be performed as follows:

Test 1 - Forward-Facing Seat, Downward, Forward, and Lateral Loads

The seat shall be installed in the vertical drop test fixture and oriented as shown in Figure C-3. A 95th percentile dummy, weighted as specified and wearing combat assault equipment, shall be placed in the seat.

The seat shall be impact tested at a vertical velocity of 50 fps. A triangular impact pulse shall be produced with a duration and peak acceleration as shown in Figure C-3.

Test 2 - Forward-Facing Seat, Forward, and Lateral Loads

The seat shall be installed in the horizontal accelerator test fixture and oriented as shown in Figure C-4. A 95th percentile dummy, weighted as specified and wearing combat assault equipment, shall be placed in the seat.

The seat system shall be impact tested at a horizontal velocity of 50 fps. A triangular impact pulse shall be produced with a duration and peak acceleration as shown in Figure C-4.

Test 3 - Aft-Facing Seat, Downward, Forward, and Lateral Loads

The seat shall be installed in the vertical drop test fixture and oriented as shown in Figure C-5. A 95th percentile dummy, weighted as specified and wearing combat assault equipment, shall be placed in the seat.

The seat system shall be impact tested at a vertical velocity of 50 fps. A triangular impact pulse shall be produced with a duration and peak acceleration as shown in Figure C-5.

Test 4 - Aft-Facing Seat, Forward, and Lateral Loads

The seat shall be installed in the horizontal accelerator test fixture and oriented as shown in Figure C-6. A 95th percentile dummy, weighted as specified and wearing combat assault equipment, shall be placed in the seat.

The seat system shall be impact tested at a horizontal velocity of 50 fps. A triangular impact pulse shall be produced with a duration and peak acceleration as shown in Figure C-6.

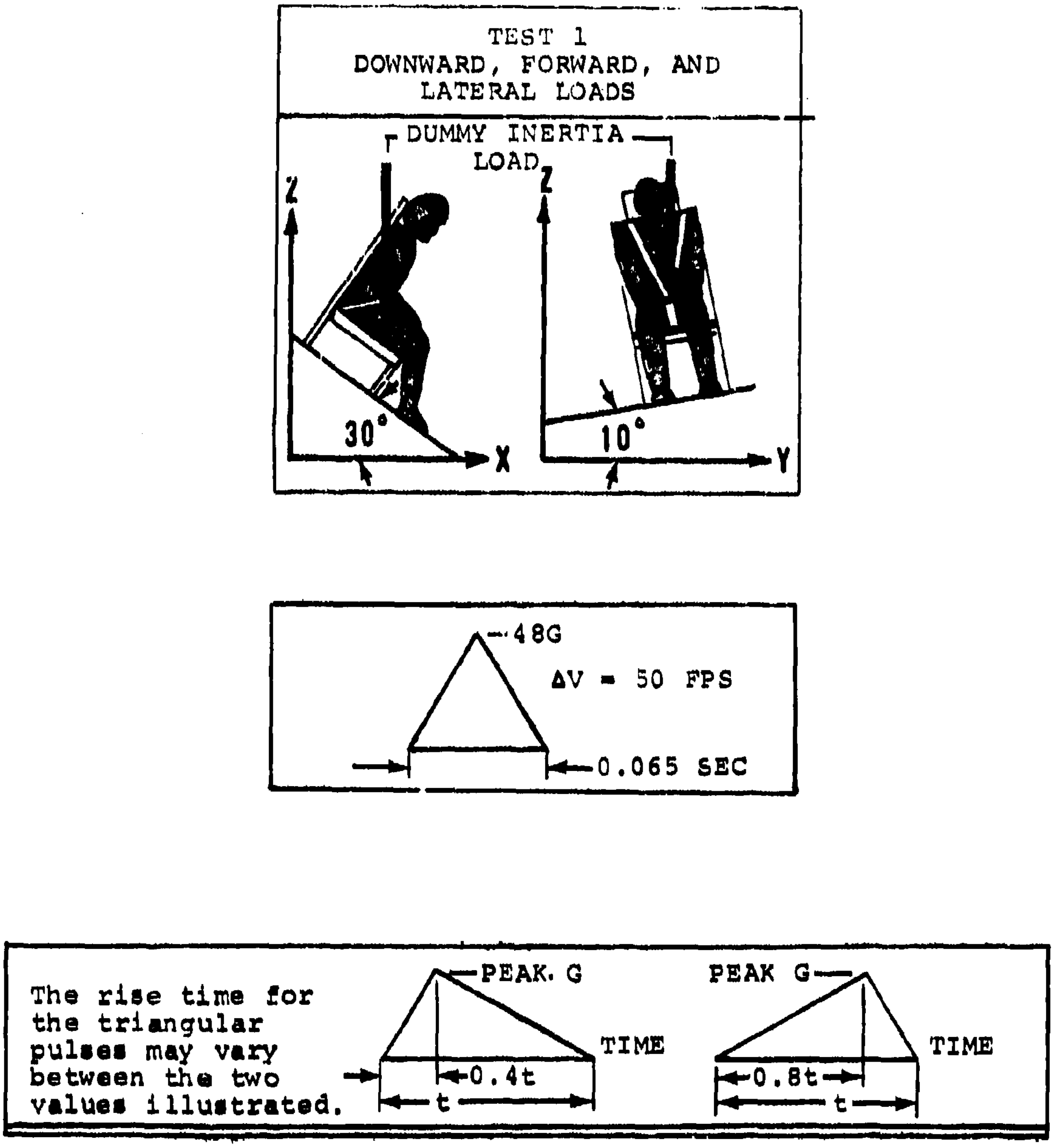


Figure C-3. Impact pulse and seat orientation, test 1.

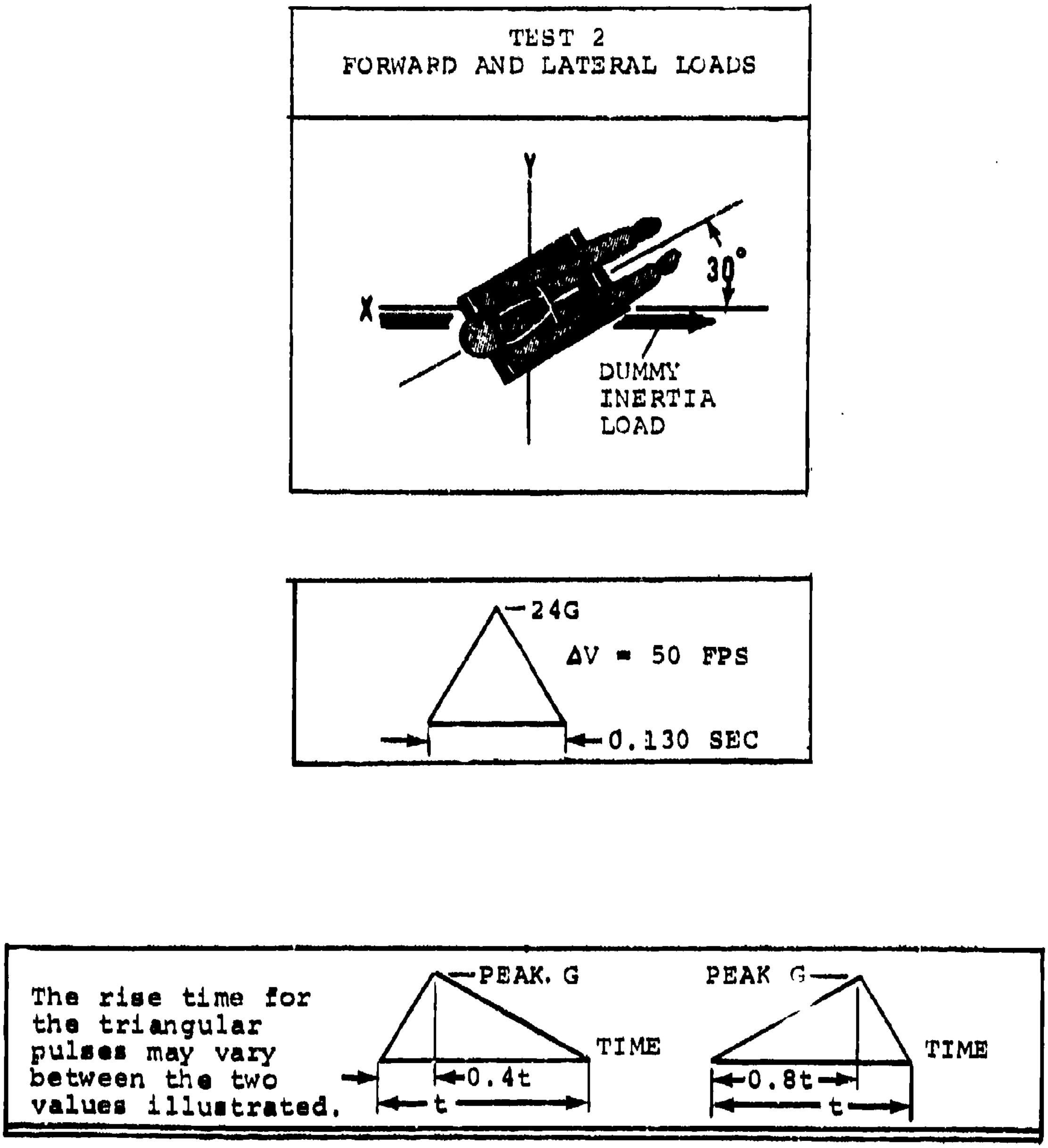


Figure C-4. Impact pulse and seat orientation, test 2.

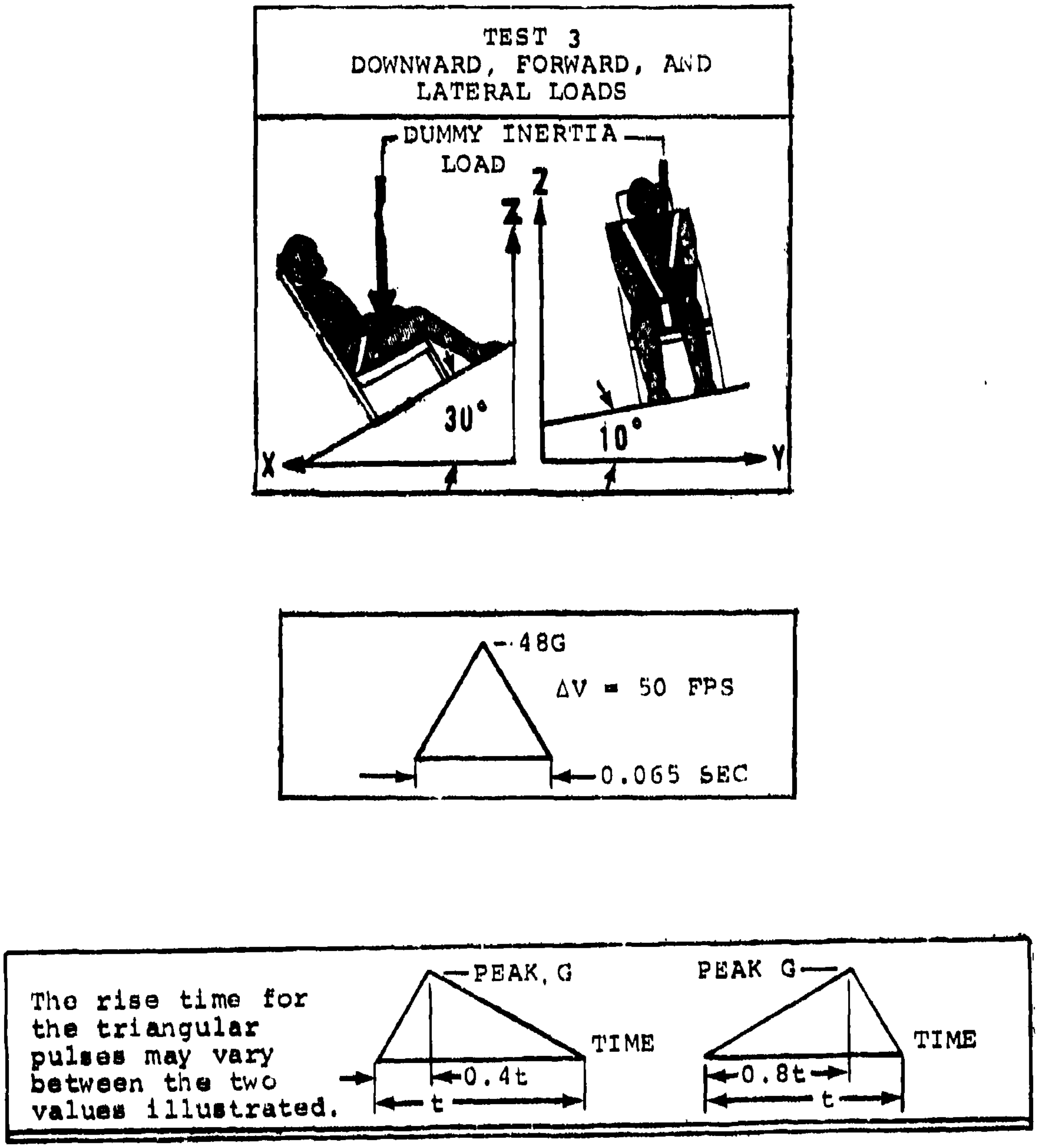
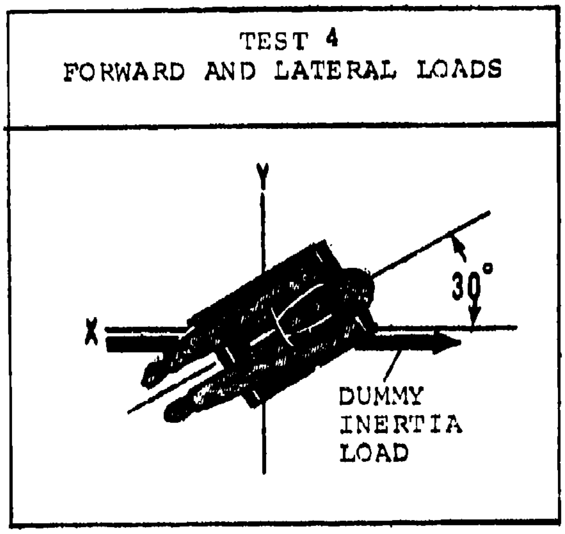
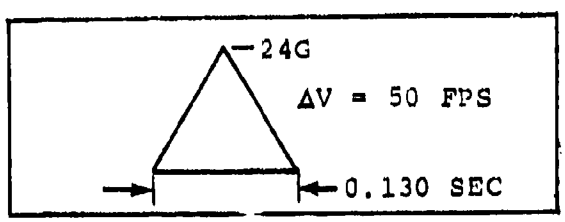


Figure C-5. Impact pulse and seat orientation, test 3.





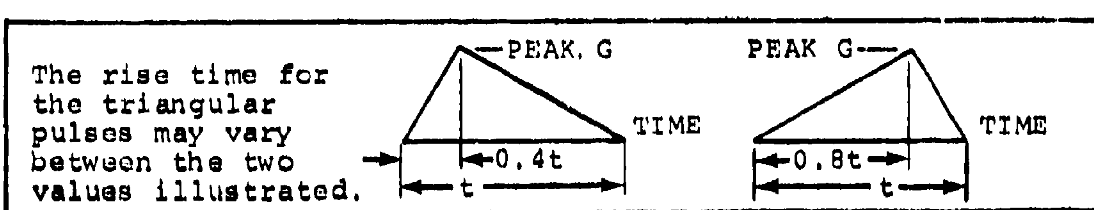


Figure C-6. Impact pulse and seat orientation, test 4.

PHOTOGRAPHIC COVERAGE

Photographs shall be taken before and after each test. Four pre-test photographs shall be taken showing the complete seat in the test fixture. The photographs shall include a frontal, side, rear, and three-quarter view. A minimum of four post-test photographs shall be taken and shall include frontal, rear, side, and three-quarter view. Additional photographs shall be taken as necessary to show failed components or deformation.

High-speed color motion pictures (400 frames per second) shall be made of each dynamic test. Three cameras shall be used providing full coverage of the front, back, and side of each seat. Redundant cameras shall be used for front and side coverage.

DATA

The data output of all instrumentation used shall be provided. The data shall be in the form of graphs showing force versus time or acceleration versus time. Deflection of attenuators shall be measured after each test. Test data shall be displayed in a form showing the degree of compliance with the dynamic test criteria, paragraph 4.5.3.2 of the draft Military Specification, Seat, Helicopter, Troop (USAAMRDL-TR-74-93).

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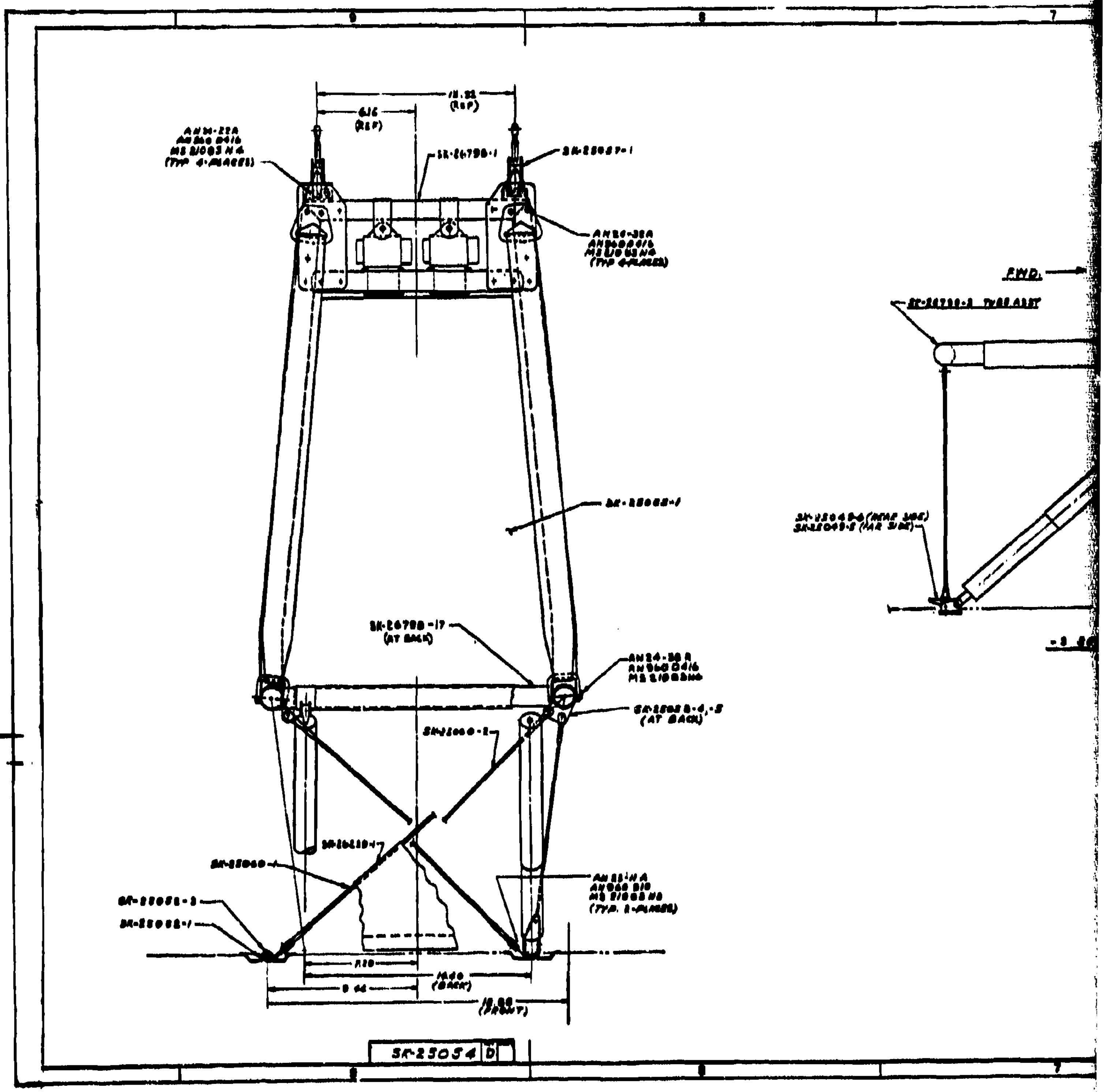
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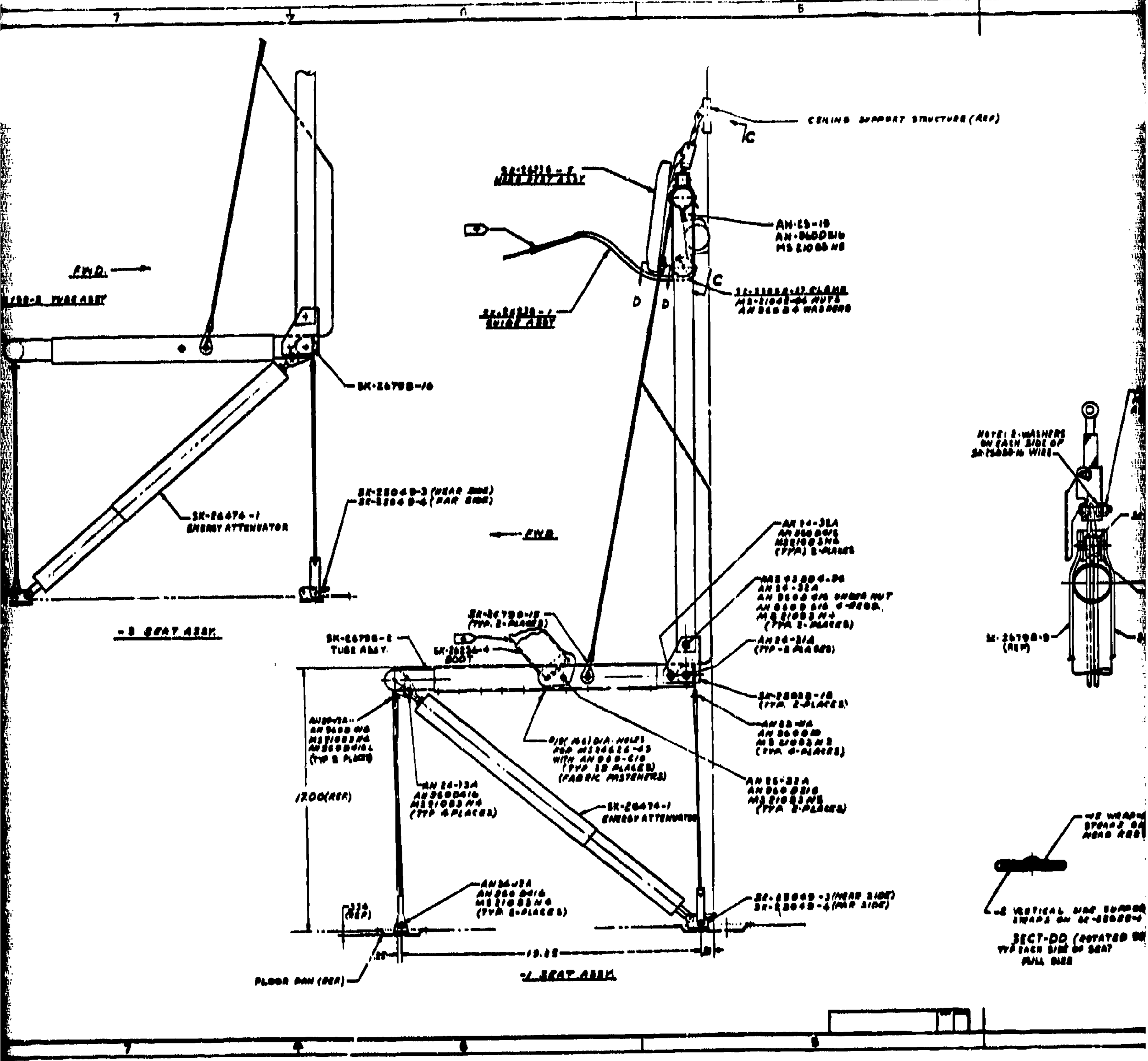


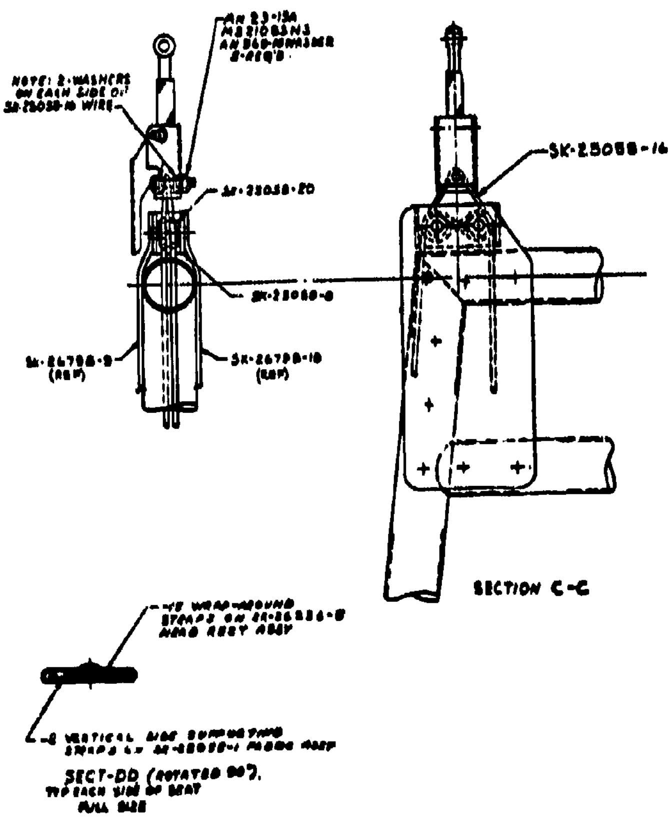
CEILING SUPPORT STRUCTURE (REF)
FWD.
SK-26758-16
SK-26474-1
ENERGY ATTENUATOR
-3 SEAT ASSY.
FWD.
SK-26758-2
TUBE ASSY.
SK-26474-1
ENERGY ATTENUATOR
12.00 (REF)
19.25
FLOOR PAN (REF)
-1 SEAT ASSY.
SECT-DD
FULL SIZE

2

CEILING SUPPORT STRUCTURE (REF)

NOTES:

1. -2 SEAT ASSY SAME AS -1 SEAT ASSY EXCEPT TWO SEATS ARE JOINED TOGETHER.
2. -3 SEAT ASSY SAME AS -1 SEAT ASSY EXCEPT ENERGY ATTENUATOR STRUTS ARE ATTACHED TO BACK OF SEAT INSTEAD OF THE FRONT.
3. SEAT ASSY TO BE SPRAY PAINTED LIGHT GREY (DULL) BEFORE INSTALLING FABRIC
4. RESTRAINT SYSTEM OPS.



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	1	SK-26798
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4	4	AN24-
2	2	AN24-
8	8	AN24-
2	2	AN23-
22	22	MS2466
2	2	AN24-
4	4	AN24-
6	6	AN24-
2	2	AN24-
2	2	AN23-
2	2	AN23-
8	8	AN960
10	10	AN960-
4	4	AN960-
22	22	AN960-
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6	6	AN960
4	4	MS2104
4	4	MS2104
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8	8	MS2104
2	2	NAS1306
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	2	SK-25068
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		SK-25054

3

ME AS -1 SEAT ASSY EXCEPT TWO SEATS
THER.
E AS -1 SEAT ASSY EXCEPT ENERGY ATTENUATOR STRUTS
BACK OF SEAT INSTEAD OF THE FRONT.
RAY PAINTED LIGHT GREY (DULL) BEFORE INSTALLING FABRIC
PE.

-SK-25058-16

C-C

REV		DESCRIPTION	DATE	APPROVED
	D	REDRAWN RESCHEDULED USING SAME DRAWING NUMBER -1 & FRAME AND SEAT MIN FRAME REF. -[illegible], 2 MAN SEAT -2 DELETED	2-8-73	[illegible]

			Part or Identifying No.	Nomenclature or Description	
	1		SK-26798-16	TUBE ASSY	
		1	SK-26798-17	TUBE ASSY	
	8	8	AN960D616	WASHER	
	4	4	AN24-22A	BOLT	
	2	2	AN24-30A	BOLT	
	8	8	AN24-22A	BOLT	
	2	2	AN23-15A	BOLT	
	33	33	MS24693-43	SCREW	
	2	2	AN24-15A	BOLT	
	4	4	AN24-12A	BOLT	
	6	6	AN24-11A	BOLT	
	2	2	AN24-31A	BOLT	
	2	2	AN23-32A	BOLT	
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	4	4	AN960-04	WASHER	
	22	22	AN960-0616	WASHER	
	33	33	AN960-C10	WASHER	
	6	6	AN-960-010	WASHER	
	4	4	MS21083-04	NUT	
	4	4	MS21083-N8	NUT	
	10	10	MS21083-N6	NUT	
	2	2	MS21083-N3	NUT	
	2	2	NAS1398C8-3	SPACER	
	2	2	SK-26836-1	GUIDE ASSY	
	2	2	SK-26836-4	LAP BELT BOOT	
	2	2	SK-25058-27	CLAMP	
	1	1	SK-26839-1	HEEL BARRIER	
	1	1	SK-26836-8	HEAD REST	
		2	SK-25062-3	SPRING	
		2	SK-25062-1	CLIP	
	2	2	SK-26798-18	HOOK	
	2	2	SK-26474-1	ATTENUATOR	
	1	1	SK-25043-1	FABRIC ASSY	
	2	2	SK-25058-16	WIRE	
	2	2	SK-25060-2	CABLE ASSY	
	2	2	SK-25060-1	CABLE ASSY	
	4	4	SK-25058-10	ROLLER	
	1		SK-25049-6	QUICK DISCONNECT	
	1		SK-25049-5	QUICK DISCONNECT	
	2	2	SK-25058-8	HOUSING ASSY	
	2	2	SK-25058-18	HINGE FITTING	
	1	1	SK-25049-4	QUICK DISCONNECT	
	1	1	SK-25049-3	QUICK DISCONNECT	
	2	2	SK-25057-1	TOGGLE LINK ASSY	
	1	1	SK-25050-5	LUG ASSY	
	1	1	SK-25050-4	LUG ASSY	
		1	SK-26798-17	TUBE ASSY	
	1		SK-26798-3	TUBE ASSY	
		1	SK-26798-2	TUBE ASSY	
	1	1	SK-26798-1	BACK ASSY	
X			SK-25054-2	SEAT ASSY	(DELETED) D
	X		SK-25054-3	SEAT ASSY	
		/	SK-25054-1	SEAT ASSY	

PARTS LIST

DAAJ02-70-C-0036

CRASHWORTHY TROOP SEAT ASSY & INSTL.

J 77272 SK-25054 D

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